IMPLEMENTATION STRATEGIES USED BY PRIMARY TEACHERS' COLLEGES TO PREPARE PRE-SERVICE TEACHERS FOR SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS EDUCATION IN HARARE METROPOLITAN PROVINCE IN ZIMBABWE

By

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DECLARATION

I solemnly declare that this thesis, entitled '**Implementation Strategies Used by Teachers' Colleges to Prepare Pre-Service Teachers for Science, Technology, Engineering and Mathematics Education in Harare Metropolitan Province in Zimbabwe'** is exclusively a product of my own research. I hereby affirm that to the best of my understanding and belief, the thesis contains no material previously published in any institution. Published and unpublished work by other scholars has been gratefully acknowledged with related sources cited both in text and in the list of references. This thesis has not been submitted to any other institution of higher learning for the award of any degree or qualification.

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ABSTRACT

The study was carried to establish the strategies used by teacher education colleges to prepare pre-service teachers for STEM Education in Zimbabwe. Invariably, the nature of research questions led the study to be located within the pragmatic paradigm. A mixed method approach and concurrent triangulation design was adopted to examine issues under study. The study adopted stratified random sampling and purposive sampling methods to identify its respondents and participants. Data were collected from respondents who were envisaged knowledgeable about critical issues under study. Several research instruments were used to solicit quantitative and qualitative data. These included: questionnaires, interview schedules, focus group discussions and documents. The sample of the study consisted of 20 lecturers, 50 pre-service teachers, 3 Department of Teacher Education lecturers and 2 Directors in the Ministry of Higher and Tertiary Education Science Innovation, Technology and Development. The study established that 95%of the teacher educators had the requisite STEM content knowledge. Pedagogical content knowledge, knowledge of organisation and education purpose, engineering content and pedagogical content was found lacking. Furthermore, the teacher educators employed 21st century STEM specific inquiry based and constructivist teaching strategies. More so, it was established that government, the Department of Teacher Education and other development partners rendered support to teacher education colleges to prepare for pre-service teachers for STEM education. In addition, the study revealed that preparation of pre-service teachers for STEM was impeded by several structural factors that obtained in teacher education colleges. Overall, the study concluded that teacher educators had requisite STEM knowledge and employed inquiry-based strategies to prepare pre-service teachers for STEM Education. Furthermore, the study recommended that teacher educators' knowledge in engineering needs further strengthening through workshops and synergies with industry. An alternative model for effective STEM preparation was recommended for consideration.

DECLARATION ON RESEARCH ETHICS CLEARANCE

I, **Ananias Chimwe**, student number **201715046** hereby declare that I am fully aware of the University of Fort Hare's policy on research ethics and I have taken every precaution to comply with the regulations. I have obtained an ethical clearance certificate from the University of Fort Hare's Research Ethics Committee and my reference number is: **REM031SCHI01**

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I, **Ananias Chimwe**, student number **201715046** hereby declare that I am fully aware of the University of Fort Hare’s policy on plagiarism and I have taken every precaution to comply with the regulations.

Signature:

DEDICATION

I dedicate this work to my wife, Queen Chimwe and my children, Tafadzwa and Tanaka Chimwe.

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ACRONYMS AND ABBREVIATIONS

AL	Advanced Level
ACC	Academic Competitiveness Council
AFT	American Federation of Teachers
Bed.	Bachelor of Education Degree
BEIS	Business Energy and Industrial Strategy
CBMS	Conference Board of the Mathematical Science
CIF	Curriculum Implementation Framework
CK	Content Knowledge
DTE	Department of Teacher Education
ECD	Early Childhood Development
FGD	Focus Group Discussion
GoZ	Government of Zimbabwe
HOD	Head of Department
ICT	Information and Communication Technology
ITEPD	Initial Teacher Education and Professional Development
ITT	Initial Teacher Training

JOST	Journal of Science Education and Technology
LIC	Lecturer in Charge
MHTESITD	Ministry of Higher and Tertiary Education, Science Innovation,
NCTE	National Council for Teacher Education
NCTM	National Council of Teachers of Mathematics
NGO	Non-Governmental Organisation
NRC	National Research Council
OL	Ordinary Level
PBL	Problem Based Learning
PBL	Project Based Learning
PCAST	President's Council of Advisors on Science and Technology
PCK	Pedagogical Content Knowledge
PhD	Doctor of Philosophy
PSA	Professional Studies Syllabus A
PSB	Professional Studies Syllabus B
SCORE	Science Community Resource Education
SMET	Science, Mathematics, Engineering and Technology
SMK	Subject Matter Knowledge
SOL	Virginia Standards of Learning
STEM	Science, Technology, Engineering and Mathematics
STI	Science, Technology and Innovation
TCDP	Teacher Capacity Development Programme
TCK	Technological Content Knowledge
	Technology and Development
TOE	Theory of Education
TP	Teaching Practice
TPACK	Technological Pedagogical Content Knowledge
TPK	Technological Pedagogical Knowledge
UFH	University of Fort Hare
UK	United Kingdom
UNESCO	United Nations Educational Scientific and Cultural Organisation

US	United States
USA	United States of America
UZ-DTE	University of Zimbabwe, Department of Teacher Education
ZFI	Zone of Feasible Innovation
ZIMDEF	Zimbabwe Manpower Development Education Fund
ZPD	Zone of Proximal Development

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CHAPTER 1
BACKGROUND OF THE STUDY

1.0 Introduction

This study interrogated strategies used in implementing Science, Technology, Engineering and Mathematics (STEM) in Teacher Education in Zimbabwe. It was motivated by the need for teacher education institutions to develop effective STEM teachers. STEM education was realised to be an integrated or interdisciplinary curriculum. It integrates science, technology, engineering and mathematics into a cohesive learning paradigm based on real world applications (Parawira, 2015). STEM teachers are key elements in the successful implementation of STEM in the classroom. Therefore, there is need to develop teachers who develop learners with the required scientific skills as recommended in STEM (Forlin, Loreman, Sharma and Earle, 2009).

This chapter serves to contextualize the problem under study. The chapter focuses on background of the study, the statement of the problem, research questions, objectives of the study, purpose of the study, significance of the study and definition of terms. A summary of the structure of the thesis is also given.

1.1 Background of the Study

In the preceding centuries, the emphasis on teaching Science and Mathematics was on sequence of lectures and reading assignments on the body of knowledge (Straver, 2007). The type of teaching did not encourage the development of meaningful knowledge which was worthwhile to the learner. Science and Mathematics were taught the same way as other subjects of the curriculum such as history. The emphasis was on rote learning and memorisation of facts (Soldat, 2009& Yager 2000). Furthermore, if laboratory activities were included, they focused only on the development of laboratory skills and techniques not constructing new ideas (Feiman-Nemser, 2000). Traditional instruction entailed making use of textbooks, worksheets and weekly experiments or demonstrations. The traditional science and mathematics teacher would read information from the textbook to the students with students required to answer questions on Science and Mathematics topics on the worksheet (Pollen, 2009). All these strategies were supposed to change in the 21st Century by the introduction of STEM in the school curriculum.

The 21st century STEM teacher should be equipped with the following skills, namely: critical reflection, reflective practice, open mindedness, critical observation and suspended judgment (Straver, 2007). Such skills are best developed through the teaching of STEM in general and inquiry- based methods (Pollen, 2009). Furthermore, problem solving is at the pinnacle of STEM learning and it is best developed through scientific based inquiry which involves identifying and posing questions, designing and conducting investigations, analysing data and empirical evidence, using models and explanations and communicating findings (Keys, 2000).

1.2 Global Context on the Preparation of Primary STEM Teachers

According to international studies consulted, most countries have given priority to the development of STEM teachers such countries are United States of America and Australia (Yager, 2005).

1.2.1 The Development of STEM Teachers in United States of America

In the United States of America (USA) training of STEM teachers at elementary level puts emphasis on programmes that provide strong content knowledge preparation, pedagogical content knowledge training, critical thinking, problem solving skills and induction support to teachers (USA Department of Education, 2002). These programmes include involving practicing teachers and administrators in teacher preparation, collaboration between faculties in STEM departments and schools of education (Yager, 2005 & Soldat 2009). Such programmes enable new teachers to develop deep content expertise as well as the teaching and learning of subject matter. They also receive good and appropriate instructional materials, clear guidance, strong administration leadership in school districts (Presidential Report, 2010 & Felman-Nemser, 2001). According to the Presidential Report (2010), there is a UTeach programme which provides classroom training and supports new STEM teachers during their formative years of teaching, including providing mentors who visit new teachers' classrooms and coach them on content specific pedagogy (Yager, 2005).

In addition to recruiting and preparing new STEM teachers, available studies indicate that effective professional development is tied explicitly to the curriculum taught to students, preparing teachers to use materials effectively based on other teachers' successes and to help address student questions (Felman-Nemser 2001). Furthermore, professional development initiatives, where teachers evaluate videos of their own teaching with a facilitator and in which teachers discuss how to evaluate and understand student progress based on assessment have been successful in the USA (Presidential Report, 2010 & US Department of Education, 2002).

1.2.2 The Development of STEM Teachers in Australia

In Australia there are two types of programmes for training STEM teachers to teach at elementary level (Sim, 2000). Both programmes are housed in University Faculties or Departments of Education. The first programme is Bachelor of Education (Elementary) category where initial STEM teachers are exposed to subject matter, content preparation and pedagogical preparation (Fitz Gerald Smith, 2016). This model is probably viewed as the most comprehensive approach for providing a sound grounding in both subject theory and practice of STEM (Sim, 2006). The second programme is the graduate entry programme which puts emphasis on pedagogical preparation more than subject area content because students enter with an undergraduate degree (McFarland, 2005). These programmes are for teachers who would have done science as a major at University. However, emphasis is on professional experience. The greater part of their learning is on complex professional work of teaching Science (Kenter, 2008).

1.2.3 The Preparation of STEM Teachers in Sub Saharan Africa

In Kenya, teacher education programmes have remained virtually unchanged since independence in 1963 (Bunji, Wangia; Magoma and Limboro, 2006). The nation's primary teacher training colleges' emphasis is on child-centered, interactive pedagogic methodologies and Science process skills (Katitia, 2015). However, these methodologies are unduly influenced by the nature and purpose of examinations administered at the end of the programme. It is, therefore, evident that, STEM subject area content is not being emphasised in Kenya (Nowel, 2007). In South Africa, the President's Education initiative of 1999, and subsequent policies asserted the critical importance of subject area competence, knowledge on specialization and ways of teaching STEM at Foundation Phase and also reflexive competence, which emphasises practical teaching competence (Rowan, 2002). South Africa has kept abreast with international best practices in initial STEM teacher development where emphasis is not only on subject knowledge and ways of teaching but on reflexive competence. However, several studies have shown that STEM implementation has encountered numerous challenges (Rowan, 2002; Sim, 2006; Parawira, 2015).

1.2.4 The Zimbabwean Context

As is the case with most developing education systems, Zimbabwe gave priority to the provision of Science, Technology, Engineering and Mathematics (STEM) (Government of Zimbabwe (GoZ), 2017). The move entails adoption of policies which were developed since the attainment of political independence in 1980. They include Zimbabwe's overall Science, Technology and Innovation (STI) regulatory framework which is outlined in a number of key protocols that include the Research Act of 1986 and its subsequent amendments; the Science and Technology Policy (ST) of 2002; the Biotechnology Policy of 2005; the Biotechnology Act of 2006; the Information and Communication Technology policy framework of 2006 and the second STI policy document of 2012 (Gadzirayi, et al 2016). The STEM Education policies in Zimbabwe emphasize that initial teacher training (ITT) programmes for primary teachers' colleges should provide hands-on and relevant learning experiences for the student teachers (Gadzirayi, et al (2016). Furthermore, student teachers should be engaged and equipped with critical thinking, problem solving, creative and collaborative skills. They should be exposed to STEM content. This exposure is assumed to enable students to apply acquired knowledge to real life projects (Parawira, 2015).

STEM Education attempts to transform the typical teacher-centered classroom by encouraging a curriculum that is driven by problem-solving, discovery, exploratory learning and requires students to be actively engage in a situation to find its solution. In Zimbabwe, STEM Education is a new paradigm that emphasises the teaching of Science, Technology, Engineering and Mathematics in an integrated, interdisciplinary and applied approach (Parawira, 2015). STEM philosophy at primary school level emphasises on an integrated teaching approach that underscores the interrelationship of Science, Technology, Engineering and Mathematics. It integrates them into a cohesive learning paradigm based on real world applications (Parawira, 2015). STEM teaching strategies at primary school, emphasises on student exploration, problem solving, strong content knowledge, and pedagogical content knowledge instead of memorizing, repetition and rote learning.

1.2.4.1 Pre-Service Primary Teacher's STEM Curriculum

The training of pre-service STEM teachers takes 3 years and follows the 2-5-2 teacher education model (Shava, 2015; Tshuma, 2009). In this model pre-service teachers spend the initial 2 terms (8 months) at college learning the Theory of Education, Main Subject (STEM) Applied Education (Professional Development Studies), and pedagogical content knowledge specific to all subjects taught in the primary school in Zimbabwe (Shava, 2015; Tshuma, 2009). Five terms (20 months) are then spent in teaching practice, attached to teacher-mentors in schools, and in the final 2 terms (8 months) the student teachers return to colleges for revision and examinations; hence the term 2-5-2 (Shava, 2015).

During their last term of teaching practice, the pre-service STEM teachers in the 2-5-2 system are subjected to an external quality assessment exercise in teaching practice which is supervised by the University of Zimbabwe's Department of Teacher Education as is mandated by the Teacher Education Scheme of Association (DTE Handbook, 2015). This is a form of summative assessment where external assessors ratify those pre-service teachers who would have successfully completed teaching practice and at the same time make recommendations to those who seem to have performed below the expected competencies. Some are required to repeat teaching practice whilst dismal failures are asked to quit the teaching profession (Smart and Csapo, 2007; Shava, 2015; DTE Handbook,2015).

The curriculum for primary STEM teachers' colleges consists of four main areas which are Content knowledge (CK) STEM/academic studies/main study/subject matter; Pedagogical knowledge (PK) STEM professional preparation, Educational foundations/theory of education; and school practice, practicum or clinical (Lynd, 2005; Darling-Hammond, 2006; Mamvuto, Kangai, Chivore and Zindi 2012), All pre-service teachers do STEM Applied Education that is the teaching methodology of STEM subjects (Mamvuto, Kangai, Chivore and Zindi, 2012; Shava, 2015; DT E Handbook,2015).

1.2.4.2 STEM Based Teaching Methodologies

According to Shamsudin, Abdullah, Yaamat (2012), teacher educators in STEM should use inquiry- based teaching strategies. Inquiry based Science include the following methods as stipulated in the policy documents in Zimbabwe, namely; simulation, field study, project, demonstration and experiment (Shamsudin, Abdullah, Yaamat, 2012; Gadzirayi, et al 2016).

Simulation is STEM based teaching consisting of role play, games and modelling Simulation using modelling is a form of experimental learning, where the learner is placed in a world made by the teacher (Perry et al, 2009). While using simulation, the learners interact with themselves, and are the test subject in the laboratory experiment. This fits very well with the principle of constructivism. Project method is another strategy teacher educator can use under inquiry methods. Past studies reveal that project work benefits students in several ways. It allows for more meaningful understanding of STEM concepts among students, enhances students' academic performance (Ojoxsola, 2007), and enables learners to engage in the processes of evaluating STEM content in authentic situations (Kanter, 2008). The project method helps teachers in the development of their STEM content knowledge (CK) as well as pedagogical content knowledge (PCK) as they prepare and facilitate students' work (Perry et al, 2009).

Demonstration is another method under inquiry. McFarland (2005) found that through demonstration the nature of the classroom interaction tends to be unidirectional as the students become actively involved in and start asking questions about the STEM content. Furthermore, McFarland (2005) discovered that the method replaces teachers as sole sources of knowledge. Resultantly, teachers become more creative while students learn to respect diversity and collaboration.

Experiment is core of doing investigation in STEM classroom. While using experiments, students find the opportunities to manipulate objects, test hypothesis and work together to solve or prove something exciting (Demeo, 2005). Demeo (2005) further notes that experiments, particularly the transformation of traditional laboratory instruction to one using teaching manipulative, helps develop more mature type of Science Education.

Field study is work on investigative studies undertaken in a natural setting, rather than in laboratories, classroom, or other structured environments (Noel, 2007). It allows students to learn STEM content or concepts through observation (structured or unstructured), discussions as well as analysis of other forms of collected date. Further, Preusch (2009) acknowledges that students develop continuity between theory and reality. While Haider (2010) asserts that teachers and students enjoy the activity and learning is made more real and more challenging. Hence, these are the training methods and strategies which were emphasised in training STEM teachers and were supposed to be used in the colleges (Yager, 2005; Soldat, 2009; Haider, 2010).

1.2.4.3 Competencies and Skills Required by STEM Lecturers

The need for quality college lecturers is key objective of teacher preparation programmes Maringe, 2005; Shamsudin, Abdullah, Yaamat, 2012; Gadzirayi, et al (2016). For the abovementioned strategy to be used effectively and the required skills to be developed in student teachers, lecturers should possess the required competencies. Therefore, lecturers should have the following competencies to achieve the quality teacher objective in STEM:

(i) They should have a strong background in STEM subjects they teach with a good linguistic and verbal ability (Whitehurst, 2004 & Maringe, 2005).

(ii) They should have strong pedagogical skills in STEM subjects and management of teaching. This positively affects teaching practice and student learning (Maringe 2005). For teacher educators to be competent, there is need for an amalgamation of teaching skills, pedagogical knowledge, and professional skills. These would serve to create the right knowledge, attitude, and skills in student teachers, thus promoting a holistic teacher development (Custer and Vries, 2011; Zvavahera, 2015).

It is important to have specialist STEM teachers to ensure effective STEM teaching in schools. Science Community Representing Education (SCORE), (2011) uses ‘specialism’ to refer to the subject knowledge gained by a teacher through their academic professional qualifications and experience and recommends the use of teachers who are subject specialists. Hence teacher educators should have the relevant competencies to equally develop the same in student teachers.

1.2.4.4 Resource and Facilities Required for STEM Teacher Education Colleges

To train effective STEM teachers, there is need to have appropriate and adequate resources and facilities. The following resources are essential: teachers, finance, classrooms, laboratories, textbooks, instructional media and furniture (Custer and Vries, 2011; Zvavahera, 2015; Gadzirayi, et al 2016). Teacher educators are an indispensable resource; however, they are likely to be rendered ineffective if they are overburdened and overloaded, have received poor training, have poor qualifications or inadequate in STEM programmes and lack of visual aids, textbooks, chemicals or teaching materials (Custer and Vries 2011; Zvavahera, 2015; Gadzirayi, et al., 2016). For the effectiveness of quality education and success of the STEM initiative, colleges should have well equipped classrooms and laboratories. Laboratories should have adequate equipment and other facilities such as common apparatus; beakers, burners, burets, clay, triangles, droppers, balances, vacuum pumps, drying ovens, centrifuges, dissolved oxygen meters, PH-meters (Zvavahera, 2015). Furthermore, well equipped laboratories and furniture may enhance the teaching and learning of STEM in teachers’ colleges. Provision of adequate resources and other facilities to enhance adequate and quality STEM teacher output has been among the most important aspects identified in the policies (Custer and Vries 2011; GoZ 2012; Zvavahera, 2015; Gadzirayi, et al., 2016).

1.2.4.5 Support System Provided in Teacher Education Colleges

The government of Zimbabwe has recently entered partnership with the Chinese government to promote the construction of schools in Zimbabwe, Gadzirayi et al (2016). It has already been noted that in 2014, the Ministry of Primary and Secondary Education launched the Teacher Capacity Development Programme (TCDP) meant to train about 5000 teachers by end of 2015 (GOZ, 2014). The government undertook to provide funds for the training of STEM teachers in teachers' colleges in Zimbabwe. The government were also to put in place retention allowances for STEM teachers to arrest brain drain in this skills group, Gadziayi, et al (2016). The Ministry of Higher and Tertiary Education, Science and Technology Development made STEM Education free at Advanced Level (AL). This initiative was aimed at encouraging more students to take up STEM with the intention of increasing the good quality teacher output in the area. The Ministry of Higher and Tertiary Education, Science and Technology Development supported colleges through policy planning and research and evaluation, (Maravanyika, 2012). Maravanyika (2012) acknowledges that the institutions division oversees what goes on in all institutions registered by HTESTDS such as teacher education. It also handles government relationship with the University of Zimbabwe (Maravanyika, 2012).

All teachers' colleges are associated with the University of Zimbabwe through the Associate College Centre, the Department of Teacher Education (DTE). While the Ministry of Higher and Tertiary Education Science and Technology Development has the overall responsibility over colleges and teacher education in general, the DTE has over the years overseen the professional aspects. As discussed in earlier sections, it approves the various syllabuses, comments on the standard of work in the colleges and certificates the successful students. Teacher Education is moderated nationwide by the University of Zimbabwe, Faculty of Education, Department of Teacher Education Maravanyika, 2012; Gadzirayi, et al (2016).

However, despite the policies that have been put in place and strategies discussed above to ensure training of quality pre-service STEM teachers there has been a number of concerns raised by stakeholders, which prompted this study on how the strategies were implemented. Some stakeholders observed with concern, that pre-service teachers lacked critical STEM aspects such as subject knowledge, pedagogical content knowledge, which includes knowledge of STEM curricula, knowledge of instructional strategies, knowledge of students' understanding of STEM and knowledge of assessment Maravanyika, 2012; Gadzirayi, et al (2016)**.** Some of these concerns have also been echoed by the University of Zimbabwe, Department of Teacher Education (UZ-DTE) who are part of the external examiners of college examinations (Dudu, 2013; Banda, 2016)**.** This is also revealed in several academic reports produced by the UZ-DTE external examiners and Chief examiners which are subsequently presented to Board of Studies and Senate Committee (UZ-DTE, 2015).

Furthermore, Parawira (2015) acknowledges that many classroom teachers who would have completed studies at the teachers' colleges required STEM content knowledge, pedagogical content knowledge and technological content knowledge, as they lacked them and they evidently exhibited inadequate initial teacher development. Moreover, studies have envisaged that some student teachers have negative attitude towards STEM. The reasons for the negative attitude are not known (Maravanyika, 2012; Gadziayi, Bongo, Ruyimbe, Bhukuvhani and Mucheri, 2016). There were also complaints from college management and other staff that there was no adequate support and monitoring extended to colleges despite the elaborate plans outlined by the government. Shortage of equipment, apparatus and chemicals was also rife in most institutions (Parawira, 2015; Dudu, 2013; Makgato and Mji 2006). Consequently, colleges lacked basic infrastructure and other facilities such as physical plant for workshops. Some stakeholders felt the impact of these shortages might have reduced the quality of college leavers and also led to some student teachers dropping out before completion Maravanyika, 2012; Gadzirayi, et al (2016). Some college managers were reported to have raised concerns that college lecturers might have been rendered ineffective by being overburdened and overloaded with work, receiving poor training, having poor qualifications or being thin in Science programmes (Parawira, 2015).

There were also complaints that there was lack of trained personnel to train the pre-service teachers to be able to handle STEM classroom. At present, teachers trained in the main-stream are equipped with both traditional and progressive methods and strategies of teaching which includes lecture methods, experimentalism, demonstration, projects, question and answer, drama, to mention but a few (Chikuni, 2002). Despite awareness and availability of policy framework for implementing teaching strategies to pre-service STEM teachers there were complaints about how the required strategies were to be implemented. Some stakeholders attributed this to lack of the required competencies by STEM college lecturers (Maravanyika, 2012; Gadzirayi, et al (2016).

Considering the above concerns, it was not quite clear as to how teachers' colleges were implementing strategies for developing pre-service teachers in Science, Technology, Engineering and Mathematics [STEM] in Zimbabwe. Hence, it became crucial to interrogate implementation strategies used to develop STEM pre-service teachers for primary schools in teacher education colleges in Zimbabwe.

1.3 Statement of the Problem

The development of STEM teachers in initial teacher education is critical for the successful teaching in schools. Observations by experienced STEM educators and University of Zimbabwe Department of Teacher Education (UZ-DTE) external assessors has shown that the initial teacher education curriculum in Zimbabwe lacks critical STEM aspects, such as, subject knowledge, pedagogical content knowledge and was taught using theory only and practical activities were not being carried out (Maravanyika, 2012; Gadzirayi, et al., 2016). It was noted that pedagogical content knowledge did not make use of enquiry based methodologies and it was not skills driven. These observations and concerns were echoed by several academic reports produced by the UZ-DTE external examiners and Chief examiners, which were subsequently presented to Board of Studies and Senate Committee (UZ-DTE 2015; Chimbodza, 2012). Some stakeholders expressed concern and even raised issues with the extent teachers were prepared to teach STEM at primary level (Driel and Bemmy, 2012). In view of the concerns raised by different stakeholders it was not quite clear on how teachers' colleges were implementing strategies for developing primary school pre-service teachers in STEM. This situation is what prompted this study, to interrogate the development of STEM teachers in teacher education colleges in Zimbabwe.

1.4 Research Questions

The researcher intended to answer the following questions:

1.4.1 Main Research Question

What strategies are used by teachers' colleges to prepare pre-service teachers for science, technology, engineering and mathematics education in Harare metropolitan province in Zimbabwe?

1.4.2 Sub-Research Questions

1.4.2.1 How competent were college lecturers in preparing pre-service primary STEM teachers?

1.4.2.2 Which teaching and learning approaches were used to prepare pre-service primary STEM teachers?

1.4.2.3 What resources, support systems and facilities were available in the colleges to develop pre-service primary STEM teachers?

1.4.2.4 Why were teachers' colleges facing challenges in implementing strategies for developing pre-service primary STEM teachers?

1.4.2.5 What framework could be developed from the findings of the study to enhance proper coordination on the preparation of pre-service primary STEM teachers by teachers' colleges?

1.5 Purpose of Study

The purpose of the study was to explore how teachers' colleges were implementing strategies used for preparing pre-service STEM teachers in Zimbabwe.

1.6 Objectives of the Study

The objectives of this study were to:

a.) Determine how competent the college lecturers were in preparing pre- service primary STEM teachers.

b.) Identify teaching and learning approaches used to prepare pre-service primary STEM teachers.

c.) Establish resource, support systems and facilities available in colleges to prepare pre-service primary STEM teachers.

d.) Develop a properly coordinated framework for preparing primary STEM teachers.

1.7 Significance of the Study

The researcher's interest was promoted by being a STEM teacher educator and external examiner appointed by the University of Zimbabwe, Department of Teacher Education (DTE) to several primary teachers' colleges. Furthermore, the review of related literature indicated that there was paucity of studies that were carried out in Zimbabwe with reference to the development of pre-service primary STEM teachers. In view of the above, this study endeavours to add voice to the development of STEM teacher educators in terms of knowledge and empowering them with the capacity to deliver STEM lectures to 21st Century pre-service STEM teachers. The findings of the study might provide policy makers, college principals, Lecturers in Charge (LICs), Head of Departments (HODs) and lecturers/ teachers educators with modern STEM teaching skills. A new STEM teacher education curriculum would be of importance to college administrators and policy makers as well as provision of relevant materials, infrastructure and trained personnel who would contribute to successful development of STEM teachers. The proposed protocol could be transformed into a national and international policy.

To add on, the study might benefit the end user, that is the learner. If effective teaching strategies are exploited, the learners' needs might be met, as affective teaching strategies enable learners to understand concepts better.

1.8 Delimitation of the Study

The study focused on the development of STEM teachers in teacher education colleges in Zimbabwe. The study focused on two primary teacher training colleges in Zimbabwe drawn from Harare Metropolitan Province. The participants were college lecturers, college management, government officials, University of Zimbabwe lecturers and final year students at the two primary teachers' colleges.

1.9 Definition of Terms

The following terms were defined in the study.

1.9.1 Teacher Education

UNESCO (1990) defines teacher education as both pre-service programmes which adopt both formal and or non-formal approaches and it is a continuing process which focuses on teacher career development. This means that teacher education takes into cognizance teaching skills and sound pedagogical theories and professional skills. In this study, teacher education is going to focus on the pre-service aspect of primary teacher career development.

1.9.2 Assessment

According to Walvoord (2004:2), assessment is the 'systematic collection of information about students' learning, using the time, knowledge, expertise and resources available to inform decisions about how to improve learning.' In this study assessment referred to the systematic collection of data about education programmes undertaken for the purpose of improving and development.

1.9.3 Instructional Methodologies

Nichols (2012) states that, strategy denotes means used in the attainment of ends. It is concerned with how one achieves stated aims. In teaching, therefore, instructional strategies are skills or styles that suit the pupils' needs, which the teacher uses to ensure effective learning (Kasambira, 2004). Instructional strategies simply refer to pedagogical techniques which help the learners in understanding what they are taught and the teacher to meet the learners' needs.

1.9.4 Implementing

Denotes putting into action plans and systems related to Science teaching (Kennedy, 2005).

1.9.5 Teaching Strategies

Refers to the structure system, methods techniques procedures and processes that a teacher uses during instruction. There are strategies the teacher employs to assist students' learning (Kennedy, 2005).

1.10 Thesis Outline

The thesis is organized into six chapters as follows:

Chapter 1: Background of the study: The chapter introduced the research problem, and interrogated the background of the study, statement of the problem, research questions, research objectives, purpose of the study, significance of the study, delimitation of the study and definition of key terms.

Chapter 2: Literature review: In this chapter, the researcher outlined the conceptual and theoretical framework of the study as well as studies that been had carried out concerning STEM in teacher education.

Chapter 3: Research methodology: This chapter focused on the study's methodological aspects, namely: research paradigm, research approach, research design, population, sample and sampling procedures and data collecting instruments. The chapter also looked at issues to do with credibility, trustworthiness and ethical considerations.

Chapter 4: Data presentation and analysis. The chapter focused on presentation of data collected and analysed.

Chapter 5: Discussion of Findings. This chapter focused on discussion of data presented and analysed.

Chapter 6: Summary, Conclusions and Recommendations. In this chapter, the study is summarised, conclusions drawn, and recommendations made.

1.11 Summary

In this chapter, the researcher provided the background of the study, statement of the problem, research questions and objectives, purpose of the study, significance of the study, delimitations of the study and definitions of key terms. The next chapter focuses on review of literature related to the study.

CHAPTER 2
REVIEW OF RELATED LITERATURE

2.0 Introduction

This chapter focused on the review of literature related to the topic under study. The purpose of reviewing literature was to determine what had already been done by other researchers and authorities in the area under study. Bryman (2012) points that the purpose of exploring existing literature is to identify what is already known about the area being investigated and also to establish what concepts and theories are relevant to this area, including finding out if there are any unanswered research questions in the area of study. A lot of research had been done in STEM education. However, not much had been researched in implementing methodologies/strategies by teachers' colleges to develop pre-service STEM teachers in Zimbabwe.

This chapter thus interrogated the following areas: theoretical and conceptual framework of the study, teaching strategies, strategies for implementing STEM education, advantages of STEM education, knowledge base for STEM teachers and other empirical studies on STEM education in teacher education in Zimbabwe and elsewhere.

2.1. Theoretical Framework

Henning, Van Ransburg and Smith (2004) assert that a theoretical framework positions a research study in the discipline or subject in which the researcher is working. This enabled the researcher to theorise his or her research and make explicit his or her assumptions about the world. This study focused on two theoretical frameworks, one related to strategies for implementing STEM education, and the other related to learning. This was necessary because strategies for implementing STEM are used on the learners who must grasp and benefit from whatever content teachers impart to them. Teachers also need to understand how children learn so that they use the most effective strategies for each learner to benefit by developing his or her potential. The two theories that were used are Constructivism and Rogan and Grayson's 2003 curriculum implementation protocol.

2.1.1 Constructivism Theory

Constructivism, rated the most influential psychology of teaching and learning, was acknowledged by most educationists as the basis of the current reforms trajectory in teaching and learning (Fosnot and Perry, 2005 and Kusi, 2017). Constructivism states that individuals generate knowledge and meaning from the interface between the individuals' experiences and their ideas (Von Glassersfeld, 2005). The theory of constructivism, which has had wide-ranging impact on teaching methods in education, underlies many education reform movements such as STEM Education in USA, Australia and Zimbabwe. Constructivism is driven by the idea that learners must construct knowledge in their own minds, rather than simply imparting knowledge to learners. Teachers are regarded as facilitators to the process of knowledge acquisition (Du Plessis et al, 2007; Geelan, 1997; and Kusi 2017).Also, it is important to note that constructivism instead of being a particular pedagogy (Cobb, 1990, Fosnot, 2005, Noddings, 1990 and Kusi 2017) is a theory defining how learning takes place, irrespective of whether the learners concerned utilize their experiences to understand a speech that they hear, or to follow the directions for constructing a model aircraft. In both cases, the concept of constructivism proposes that learners construct knowledge out of their own experiences. Additionally, in building personal cognitive understanding, students construct and reconstruct their social reality (Reusser and Pauli, 2017). The basic tenets of believing in constructivism are:

i. Learner centeredness.
ii. Teacher as a member of the learning community.
iii. Teacher as coach, mentor, and facilitator.
iv. Learning as a social and collaborative endeavour.
v. Assessment as being interwoven with teaching.
vi. Emphasis on discovery and constructing knowledge.
vii. Emphasis on application and understanding, and
viii. The pursuit of student questions, which are highly valued (Forier and Desly, 2007 and Kusi, 2017).

2.1.1.1 Types of Constructivism

There are basically three types of constructivism; these are: exogenous, endogenous and dialectical. In exogenous constructivism, as with the philosophy of realism, there is an external reality that is reconstructed as knowledge is formed (Kusi, 2017). Thus, one's mental structure develops to reflect the organization of the world (Dogni and Kalender, 2007). The information processing conceptualizations of cognitive psychology emphasize the representation view of constructivism, calling attention to how we construct, and elaborate schemata and networks of information based on the external realities of the environments we experience (Kusi 2017). Endogenous according to Cobb, 1994, focuses on the internal, individual constructions of knowledge. This perspective, which is derived from the Piagetian theory (Piaget 1977, 1970) emphases individual knowledge construction, stimulated by internal cognitive conflict as learners strive to resolve mental disequilibrium. Essentially, children as well as older learners must negotiate the meaning of experiences and phenomena that are discrepant from the existing schema (Kusi, 2017). More so, students may be said to author their own knowledge, advancing their own cognitive structures by revising and creating new understandings out of existing ones. This can be accomplished through individual or socially mediated discovery – oriented learning activities (Dogni and Kalender, 2007).

On one hand, dialectical or social constructivism views the origin of knowledge constructions as being the social intersection of people, interactions that involve sharing, comparing and debating among learners and mentors (Brown and Duguid, 1989, Rogoff, 1990). Through a highly interactive process, the social milieu of learning is accorded center stage and learners both refine their own meanings and help others find meaning (Kusi, 2017). In this way knowledge is mutually built. This view is a direct reflection of Vygotsky's (1978) social-cultural theory of learning which accentuates the supportive guidance of mentors as they enable the apprentice learner to achieve successively more complex skills understanding, and ultimately independent competence (Kusi, 2017).

Furthermore, below is a summation of the different forms of constructivism:

Table 2. 1 Forms of Constructivism

	Type of Constructivism	Originator(s)	Description
1	Personal Constructivism	Kelly and Piaget	Emphasises the ideas that individuals construct knowledge for themselves through constructing the repetition of events. Emphasises that knowledge is individual and adaptive rather than objective.
2	Radical Constructivism	Von Glaserfeld	Claims that knowledge is not transferred directly from the environment or other persons into the learner but must be actively constructed within the individual mind for the purpose of survival.
3	Social Constructivism	Solomon	Believes that ideas are held by individuals. Emphasizes the social effects of the desire for consensus and peer approval. Describes two separate domains knowledge that are difficult to bring together, namely socially acquired life world knowledge and symbolic school knowledge.
4	Critical Constructivism	Taylor	Suggests that the process of teaching and learning are socially repressive myths such as cold reason and hard control, can lead to the failure of constructivist reforms in classrooms. Suggests that constructivism can most fully fulfill its potential through social reconstruction, and that emancipator interests must overcome the existing technical rational status quo.
5	Contextual Constructivism	Cobem	Agrees with Solomon on the importance of social interactions for human cognition, adding culture as a central force in the development of ideas.

Source: Adapted from Venter, (2001, p.88)

From the above discussion, one can observe a common trend running through the five mentioned forms of constructivism. The main point of departure is how the knowledge is constructed, and who is involved in the process of its construction. Further, the central principle remains that knowledge is constructed, and that it is not transferred directly from the teacher, the environment, or other persons to the learner (Kusi, 2017).

Constructivist learning suggests that the starting point is what knowledge is, and how it is constructed by the learners. The proponents of constructivism concur that learning is a dynamic process of constructing, understanding and that it is not a passive process of receiving information. The constructivist methodology can be adapted to any STEM subject or educational programme by means of involving the learner, their own knowledge, instead of them being inactive beneficiaries of the knowledge that is transmitted to them by the teacher. The use of the constructivist approach can be incorporated into one - hour lecture periods, to teach a particular concept, skill or attitude (Gagnon and Collay, 2010 and Kusi, 2017).

Constructivism was incorporated into this study because it determined the teaching methodology suitable and relevant to pre-service teachers in teacher education colleges. Constructivism also postulates how learning by pre-service teachers should take place, especially for STEM Education. There are aspects which this study further explored.

2.1.1.2 Criticism of Constructivism

Constructivism is besieged with several criticisms. It is regarded by some as a mere compelling hypothetical premise for a rational curriculum, particularly, for the teaching and learning of the basics of STEM subjects. (Schollar, 2008).

Several teachers (Kirschner, Gwellwe and Clark, 2006; Mayer, 2004 and Tambara, 2015) were said to have questioned the effectiveness of constructivism in relation to instructional design as it applies to the general development of instruction for beginners. Although, some constructivist maintained that learning by doing improves learning, opponents of constructivists claim that only slight experimental proof exists to back this declaration in terms of the context in which learners are meant to learn (Kirshner et al, 2006; Mayer, 2004; Tambara, 2015 and Kusi, 2017). Learners were claimed to lack the fundamental simulations or schemas, that are necessary for learning by doing.

Mayer (2004) argues that not all the teaching techniques that are based on constructivism are efficient or effective for all learners. Abadzi (2006, p. 76) concurs that ‘While there are many enthusiastic articles about the constructivist philosophy, there is little hard evidence regarding its benefits for poor In addition, Mayer (2000, p. 15) suggests that many teachers misplay constructivism as a means of employing teaching techniques that require learners to be behaviorally active. He describes this inappropriate use as the constructivist teaching. Therefore, Mayer (2000, p. 15) proposes that learners may be “cognitively active” during learning and that the teachers concerned should use guided practice.”

Kirschner, et al (2006) describe constructivist teaching methods as being unguided methods of instruction. They suggest, in preference, more structured learning activities for learners with little or no prior knowledge. Furthermore, Mayer (2008, P. 339) posits that constructivism “is an example of fashionable but thoroughly problematic doctrine that can have little benefit for practical pedagogy or teacher education.” However, the following are studies that indicate the advantages of using constructivism in the teaching and learning process:

Response to Criticism

The following studies provide supporting evidence of the success the constructivist problem solving and inquiry learning methods

2.1.1.3 The GenScope Project

Learners using the GenScope software, which is an inquiry – based science software application, showed significant gains on the control groups, with the learners doing the basic courses (Hmelo – Schner and Duncan, 2007).

2.1.1.4 Study by Geier

Geier's study focused on the effectiveness of inquiry- based Science instruction of middle school learners, as demonstrated by their performance on high-stakes standardized test. The improvement involved was 14% for the first cohort of learners, and 13% for the second cohort. The study also found that inquiry-based teaching methods greatly reduce the achievement gap experienced by African-American learners (Hmelo-Siher and Duncan, 2007).

2.1.1.5 Concept – Oriented Reading Instruction (CORI)

This comparative study compared three instructional methods for 3rd Grade reading, traditional reading- approach, a strategies instruction only reading approach, and a reading approach with strategies instruction, and with constructivist motivation, techniques including learner choices collaboration, and hands-on-activities (CORI) resulted in the improvement of learners' reading comprehension, cognitive procedure, and motivation (Guthrine, 2004).

2.1.1.6 Jong Suk Kim Study:

This study found that the utilization of constructivist teaching methods with 6th graders enhanced learners' achievement rates more than did the utilization of traditional teaching methods. In addition, the study, Kim (2005) found no difference in learner self- concept, or in learning strategies between those who were taught by constructivist methods, and those who were taught using traditional methods (Kim, 2005).

2.1.1.7 Dogni and Kalender Study

This study compared classroom using traditional teacher-centered methods in contrast to those using constructivist learner-centered methods. In their initial test of learner performance, immediately following the lessons, they found no significant differences between classes that were taught using constructivist methods. However, in the follow – up evaluation, which took place after 15 days, learners who had learnt through constructivist methods indicated better knowledge retention than did the learners who had learnt the same subject matter through conventional methods (Dogni and Kalender, 2007).

2.1.2 Summary on Implications of Constructivism

Constructivism found prodigious relevance in this study on implementing strategies used by teacher education colleges to develop pre-service teachers for STEM education, in Harare province, due to the realization that teaching does not take place in a vacuum but in a social setting. The learning of STEM education needs to be understood in the context of their social settings over time. Any STEM education strategy must be informed by constructivism approach. The constructivist approach emphasises the following teaching methods of STEM Education, experimentation, problem solving, project-based learning, and enquiry-based instruction (Katukula, 2018). STEM teaching methods based on constructivist views are useful in helping student teachers learn STEM Education disciplines. Thus, a close look at constructivist theory enabled the researcher to understand and appreciate the STEM Education instructional methodologies in teacher education colleges in Harare province.

2.2 Rogan and Grayson's Theory of Curriculum Implementation

As cited previously, this study was also informed by the curriculum implementation theory developed by Rogan and Grayson (2003). The theory is about how teachers implement a new curriculum and the factors that influence the way they implement this curriculum, according to AIdous (2004), Rogan and Aldous (2005) and Rogan, (2007). The chosen theoretical framework befitted curriculum implementation in STEM and in the context of a developing country, such as, Zimbabwe. It was relevant to the interrogation of the implementation of STEM in teacher education colleges. STEM education as a curriculum innovation was introduced by the government of Zimbabwe to promote industrialization and economic growth. The curriculum implementation proposition by Rogan and Grayson (2003) was found to be quite suitable to this study.

The theoretical framework for implementation is premised on the need for starting by recognizing current reality then moving on to build on the strength of various components of the educational system, such as, teachers, learners and school environment (Molapo and Pillay, 2018).

The framework of curriculum implementation has three constructs at its heart, namely: a profile of implementation, capacity to innovate and outside support (Hattingh, Aldous, and Rogan, 2007, and Molapo and Pillay, 2018). Each allows one to identify the extent to which the curriculum is practiced. Each of the three constructs can be utilized to help understand, analyse and express the extent to which the ideals of a curriculum of STEM are realized in context.

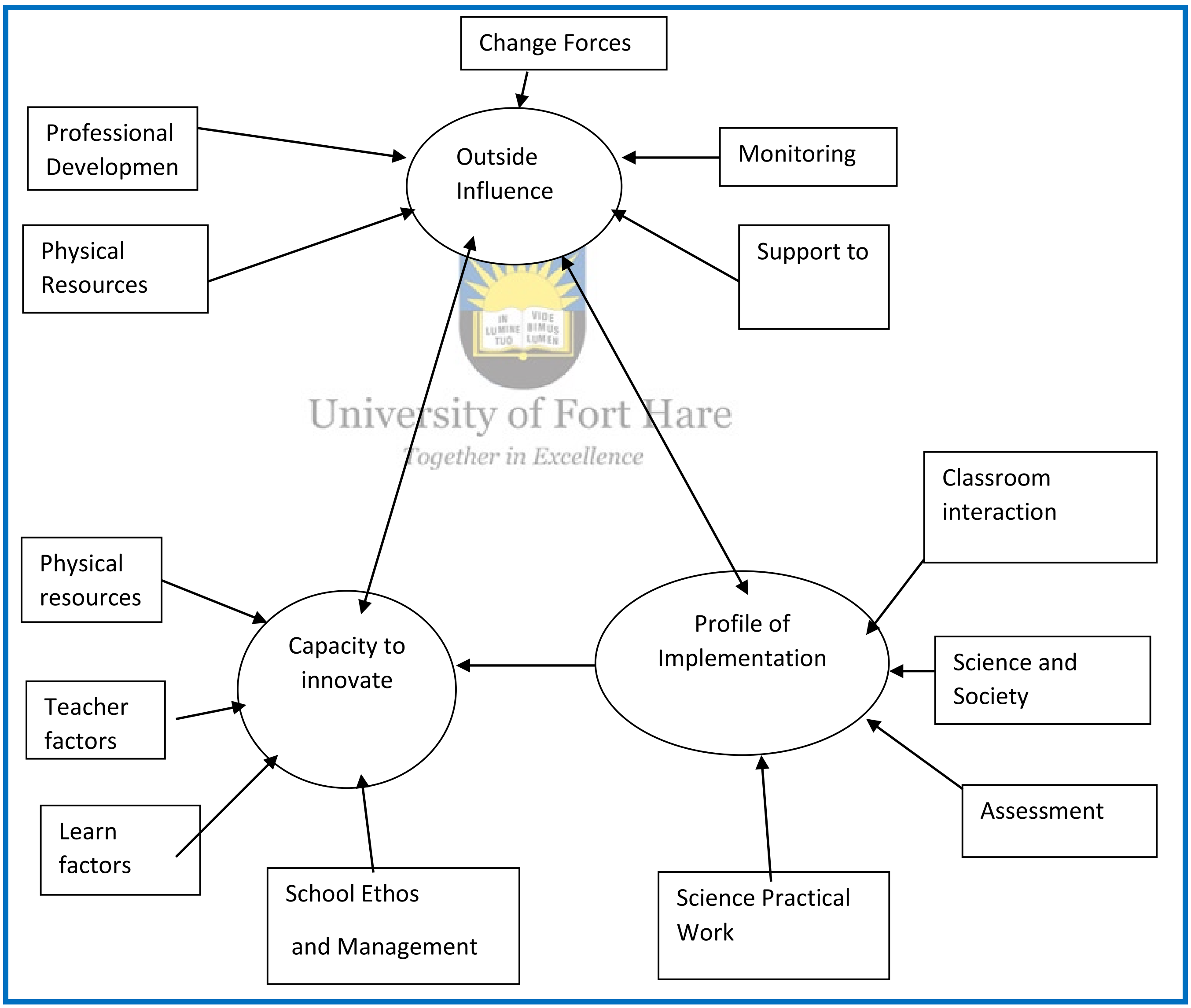

Figure 2. 1 Framework of Curriculum Implementation
Source: Adapted from Rogan and Grayson (2003)

According to Molapo and Pillay (2018), the construct “capacity to innovate” consists of four sub-constructs: physical resources, teacher factors, learner factors and school ethos and management. Capacity to innovate shows how the school context can support or inhibit curriculum implementation. Physical resources, these can be differentiated into human-resources which relate to the availability and unavailability of teachers in a school and non-human resource in the form of lecture rooms, furniture or media centers with books and stationery and textbooks for school teachers. Other resources may be indirectly involved with teaching in the classrooms but may impact negatively on it if they are not available, for example, toilets, secure premises and well- kept grounds. Poor resources may hinder performance of the learners (Molapo and Pillay, 2018).

There is teacher factor, under capacity to innovate. These refer to the teachers’ ability to teach depending on qualifications, experience, professional development as well as the teacher’s knowledge and their pedagogical content knowledge. The next sub-construct is the learner factor; this concerns itself with barriers experienced in terms of the language of teaching and learning and the support that learners derive from their homes in doing their school work as determining factor for the success. Their background also detects the strength and shortcomings they might bring to the learning situation. The next sub-construct under capacity to innovate is the school ethos and management. It involves the role played by school management/leadership in maintaining a healthy and conducive environment where teaching and learning takes place effectively. It also involves the support the school executive provides in terms of the equipment and the relevant resources. In addition, levels in the capacity to innovate and in the profile of outside support represent a progression towards a greater capacity to implement.

The next construct is the profile of implementation aspect of Rogan and Grayson’s (2003) curriculum implementation theory; it focuses on teacher’s classroom practices. In other words, it looks at what teachers do or are unable to do in the implementation process. The profile of implementation allows one to identify the extent to which the curriculum is practiced in the classroom (Hattingh, Aldous, and Rogan (2018). Levels of the profile of implementation are described within each sub-construct (Rogan and Grayson, 2003). The levels describe teachers' increasing repertoire of practice in which higher levels include lower levels of practice. The four sub-constructs of the profile of implementation are the nature of classroom interaction (what teachers and students do in relation to one another, STEM practical work, and incorporation of STEM in society and assessment practices).

The classroom interaction sub-construct is concerned with what the teacher and learners do during the development of the lesson. The literature reviewed attests to several reasons that contribute to implementation problems in Zimbabwe as well as in other countries, such as, USA (Motswini, 2004).

Furthermore, Science practical work sub-construct is about the engagement of the Science teacher and the learner in addressing intended learning outcomes which is about scientific investigations. It promotes critical thinking and the ability to participate in decision-making in an informed way (Doe, 2012).

The next sub-construct under profile of implementation is the incorporation of Science in society. This is clearly spelt out in the level 1, Science, society and the environment must relate to the aspects that impact on the well-being of the society and the environment. This is a paradigm shift from prescribed content to a contextualized content to meet the needs of the society and to address the knowledge, skills and values as set out in the assessment standards of every grade in a conceptual progression (Molapo and Pillay, 2018).

The last sub-construct is assessment under the profile of implementation. Assessment will only be noted as part of lesson planning. It will be checked if the form of assessment used at different levels appropriate to the level in question without considering the learners' responses because the study is only about teacher implementation.

2.2.1 Support from Outside Agencies

Provision of resources is crucial to learning and functionality of the school (Heson, Kahle, Scanteleybury and Davies, 2001). According to their study, one of the main indicators of access to quality Science education was resources and teacher support. A positive base to bring a favourable climate in school is critical as an unfavourable climate interferes with the learners' opportunities to learn. It has been observed that negative environments may lead to learners disengaging from school and learning. (Hewson et al, 2001, Molapo and Pillay, 2018). The support they referred to is offered in the form of material things such as human resources, buildings, books and apparatus (Motswiri, 2004, Garegae, 2003, Koosimile, 2002, Hewson et al, 2001 and Molapo and Pillay, 2018). Material support is also extended to learners in the form of provision of support of accommodation and meals. Non- material support can also be viewed as taking the form of in-service professional development and monitoring of the implementation. Brown and Schulze (2002, Molapo and Pillay,2018) talked of human resource support bringing a good environment for the health and welfare of the institutions.

However, the most important feature of Rogan and Grayson's (2003) framework is their idea of a zone of feasible innovation (ZFI) which is relevant to this study. Identification of a ZFI is a key feature since according to Rogan and Grayson (2003), schools differ in many important aspects bringing in the need to treat each school differently. Its identification allows the different approaches when a new curriculum is introduced. More so, to understand the ZFI concept, it is important to first look at what Rogan and Grayson (2003) call the levels of operation.

2.2.2 Operational Levels

Rogan and Grayson (2003) attempted to categorise practice, capacity, and support in stages called levels of operations progressing from lower to higher levels of development. Levels of operation are identified by the level of development of practice going on in a particular situation (Tawana, 2009). The use of levels becomes clear based on these, the likely effectiveness of future interventions can be indicated. The implications are that the higher anticipated levels of practice, capacity or support with time become the actual or current level in the future.

(Hewson et al, 2001, Tawana, 2009, Molapo and Pillay, 2018) also found the notion of levels useful in identifying readiness for and progress toward reform. Working with smaller bits is similar to the notion that learning is possible if the more complex structures are based on simpler structures and not simply an external reinforcement have, greater impact (Hewson et al, 2001, Sadovnik, Cookson and Semel, 2001, Tawana, 2009 and Molapo and Pillay, 2018). According to Rogan and Grayson (2003), different schools and teachers have irregular starting points in terms of physical resources, school environments and even classroom practice. Varied operational levels between schools make it problematic to bring pre-specified remedies since the framework does not advocate a one size fits all approach (Molapo and Pillay, 2018).

2.2.3. The Zone of Flexible Innovation

The theory of curriculum implementation by Rogan and Grayson (2003) is part of chosen framework for the study can be summed up as being guided by what they called the zone of feasible innovation (ZFI). According to the ZFI concept, schools differ, bringing in the need to allow for differences in degrees of implementation.

The ZFI (Rogan and Grayson, 2003) relates to the idea of zone of Proximal Development, ZPD (Vygotsky, 1978). Vygotsky referred to new learning occurring in what he termed "The Zone of Actual Development." He identified this as learning a child can only achieve with the assistance of an expert or a capable peer. He referred to this assisted learning as taking place in 'The Zone of Proximal Development". The gap between the actual and proximal development depicted what he called ZPD, which showed the extent of potential growth that can occur. The concept of a ZPD has powerful implications for teaching and learning for learners, teachers and curriculum development. According to Wertsch (1987), learners can perform tasks beyond their actual development levels. He observed that medication by an expert or a capable peer led to learning to different degrees. The implications are that the current ZPD level with time becomes the actual level in future.

2.2.4. Determining the Zone of Feasible Innovation (ZFI)

Examining a STEM curriculum innovation using the idea of a ZFI involves doing more than just establishing that the curriculum implementation is in fact happening. The ZFI could be described as the gap that exists between the current practice and the desired curriculum intentions. Figure 2 attempts to capture the concept of the ZFI in relation to current practice.

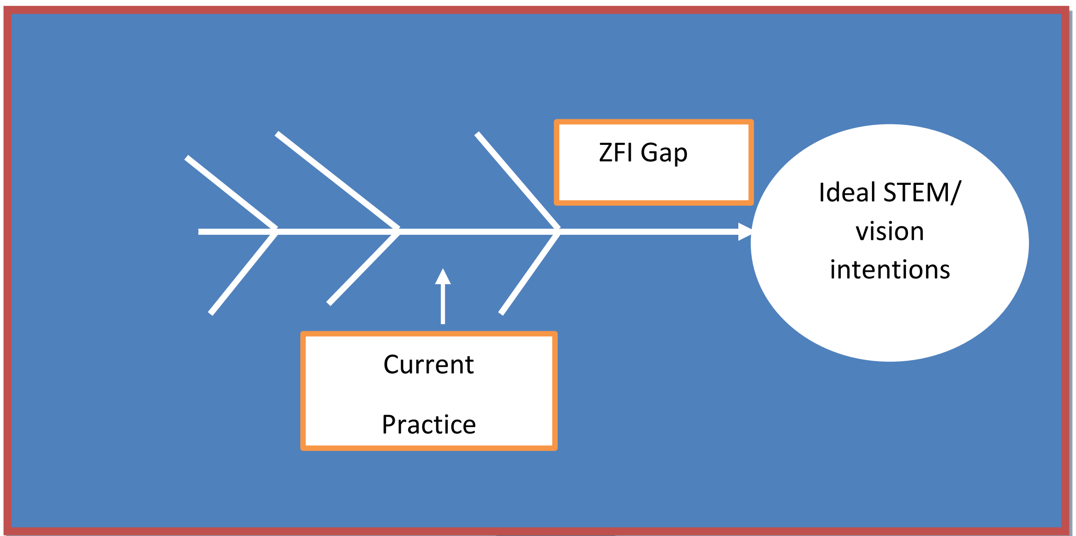

Figure 2. 2 Zone of Feasible Innovation-The Gap between current and ideal practices

Source: Adapted Rogan and Grayson (2003)

One view the ZFI is that it is a gap within a practice when the activities within current practice are not yet fully developed. It can be viewed as the gap existing between current practice and the next level.

According to Rogan and Grayson (2003), the gap is a zone of flexible innovation, innovation is likely to take place when it proceeds just ahead of existing practice. Implementation of an innovation should occur in manageable steps.

The implications are that educational innovations requiring large leaps that fall outside the ZFI's of a school are thought to be unlikely to cause any effective change, just as teaching of new ideas outside the learners ZPD are ineffective (Rogan, 2007, Rogan and Aldous, 2005, Vygotsky, 1978). According to these ideas, a school's current development level, equivalent to Vygotsky's level of actual development should be determined in order that the current strengths could be enhanced while retaining the good practices and ideas from lower level (Rogan and Aldous, 2005). The notion of ZFI can be viewed as useful because of the notion that for every school, there is a next step for development. Identifying current practice in a school makes it possible to identify the ZFI of that school. A summary of steps to current practice in a school coming from various sources points towards the following (Rogan and Grayson, 2003 and Molapo and Pillay, 2018).

- A creation of a vision of what the school should look like.
- Making a compilation of the current situation from three constructs (Rogan and Grayson, 2003).
- Identifying strength and weaknesses of the current system considering the ideals.
- Target priority items for improvement in line with what appears achievable.
- Establish a plan for addressing these priority items, finding a way to gauge success.
- Assess progress regularly and revise actions as needed.
- Take stock again and use feedback to revisit vision and begin cycle again when the action cycle is completed.

In this study, the vision of what the college system should be was goal of STEM curriculum. A close analysis has revealed that the demands of STEM correspond with the higher levels of operation in the Rogan and Grayson (2003). The ideals of the curriculum are considered the yard stick, against the current practice was measured.

2.2.5 Usefulness of the ZFI as Part of the Framework

The ZFI as the key feature of the framework for this study is useful because of its ability to identify knowledge base for growth, measure or guide success, identifying the gap can be the target for improving the change processes or areas within the sub - constructs that are still low. Accordingly, the ZFI offers a useful consideration when analyzing implementation. Furthermore, guidance by the framework makes it possible to guard against adopting the implementation universally because movements from the lower to higher levels of implementation differ. This becomes clear to see because of the various factors at play such as related to capacity to innovate profile (Rogan and Aldous, 2005, Rogan and Grayson, 2003). Due to these differences, the amount of change required by a school to move from one level to another are not expected to be the same. More so, in all three profiles it is possible to grade the level of curriculum implementation, support or the capacity to implement a curriculum. Two diagrams will be used to illustrate how the degree of curriculum implementation, capacity or support rendered to implement curriculum could be determined. According to Rogan and Grayson, the four levels of operation can be used to explain three constructs.

Furthermore, four levels ranging from 1 to 4 and increasing in sophistication have been defined for each sub-construct. Using the profile of curriculum implementation as an example, the increase in sophistication shows a progression from teacher-centeredness to more learner-centered orientation to teaching and learning. (Rogan,2007). At higher levels, also depicted learner activities become more open-ended and investigative in nature (Abdl-EL-Khalick, Boujaoude, Duschl, Lederman, Mamlock-Naoman, Hofstein, Niaz, Teagust&Taun, 2004; Motswiri, 2004; Molapo & Pillay, 2018). The highest level of operation shows the kind of practices envisaged by the STEM education in Zimbabwe.

Zimbabwe was implementing STEM education innovation in colleges; curriculum implementation framework was seen relevant to teacher education colleges implementing STEM as it spelt out the basic tendencies that any curriculum implementation should have. Further to that, STEM education is a Science, therefore, it was found relevant to teacher education colleges implementing STEM in terms of resources, facilities and support systems available in teacher education colleges.

2.3 Constructivism Theory and Curriculum Implementation Framework Interface

The two theoretical frameworks have common ground and should be blended in implementing strategies by teacher's colleges in the context of STEM education. Constructivist theory focused on how knowledge is constructed by pre-service STEM teachers while learning STEM education disciplines. Constructivism further alluded to STEM specific delivery methods for pre-service teachers, meanwhile, curriculum implementation theory focused on how the STEM curriculum innovation was implemented in primary teacher's colleges. They both focused on STEM that is how it is facilitated and implemented in teacher education colleges. They are interrelated in that constructivism focuses on STEM methods while curriculum implementation prescribes the relevant resources, facilities and support systems in which these methods are facilitated. The two frameworks focused on the nature of the teacher who is going to facilitate methods and implement the innovation in the teacher education colleges. There is a symbiotic relationship between the two frameworks in that teaching and learning methods are best facilitated in an environment with suitable infrastructure with teachers who are capable, where there is support from different stakeholders outside the college system.

2.4 Major STEM Education Themes and Perspectives

The conceptual framework for this study focused on educator's knowledge, teaching strategies, support, monitoring and challenges faced when implementing STEM. Outlined below are major STEM education implementation themes and perspectives.

2.4.1 Historical Aspects of STEM

STEM education was originally called Science, Mathematics, Engineering and Technology (SMET), according to Sanders (2009), and was initially created by (NSF). It was meant to provide all students with critical skills that would make them creative problem solvers and ultimately more marketable in workforce. Although the use of STEM concepts (historically) was being implemented in many aspects of the business world that is the industrial revolution. Thomas Edison and other inventors utilised traditional educational ideas of STEM. The use of STEM was primarily used in engineering firms to develop revolutionary technologies such as the light bulbs, automobiles, tools and machines, among others. Many of the people responsible for these innovations were only slightly educated and or were in some type of apprenticeship for example, Thomas Edison did not attend college (Beals, 2012) nor did Henry Ford, although Ford did work for Thomas Edison for a number of years, these giants of innovation used STEM principles to develop some of the most prolific technologies in history. However, STEM in education was virtually non-existent (Butz et al, 2004).

STEM education was the result of several historical events, the world war 2 and the launch of the, then Soviet Union's Sputnik.

World War II

The technologies invented and implemented during the world war are almost immeasurable. From the atomic bomb and other types of weaponry to synthetic rubber to numerous types of transportation vehicles both land and water was clear that American innovation was at play. Scientists, mathematicians and engineers many from academic, worked hand in hand with the military to develop innovative products that helped win the war and to further STEM education (Judy, 2011).

The Sputnik

In 1957, Soviet Union (Russia) successfully launched Sputnik I. this was a satellite that was the size of a beach ball and orbited the earth in about an hour and a half. Kelly (2012) states that Americans were shocked when the Russians put the Sputnik satellite into space in 1957 and grabbed a lead in global technology. USA, responded with a massive push to upgrade Math and Science Education, to have a more robust STEM curriculum

The above discourse addressed the genesis of STEM in the United States of America and the Soviet Union. The focus of STEM in America by then was the development in engineering technologies. The historical events of the world War 2 and the launch of the Sputnik by Soviet Union led to America realizing that it was lagging in global technology. Americas response was the introduction of intensive mathematics and science education in the school curriculum. This led to contemporary STEM in America and around the globe.

2.4.2 Contemporary Aspects of STEM Education

There are many variations and opinions of what STEM education is and how it should be taught.

STEM Conception

White's definition which referred to STEM education as an acronym which stands for Science, Technology, Engineering and Mathematics. Australian Council for Education Research (2016) defined STEM as a term used to refer correctively to the teaching of the disciplines within its umbrella Science, Technology, Engineering and Mathematics. Basham and Marino (2013) in Ntemngwa and Oliver (2018) described STEM as representation of educative efforts that exploit a symbiotic relationship among the four interwoven fields. This definition of STEM stressed the interdependence of the four disciplines. Tyson, Lee, Birman and Harrison (2003) in Gonyea (2016) define STEM as conglomeration of the four disciplines and the four subjects together are actively involved in providing many of our modern conveniences. Tsupros (2008) defines STEM as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real world lessons as students apply Science, technology, engineering and Mathematics in contexts that make occupations.

Science is a broad descriptive term that acquires specificity when it defines a particular field of study such as physics or better still molecular physics. The function of Science is to discover and advance knowledge. Science makes use of the scientific tools of investigation and relies heavily on Mathematics as an analytical tool. As formal fields of study, Science and Mathematics have a close symbiotic relationship. Instruction in both fields tends to convey a broad and deeper understanding of the Organisational substantive and syntactical structures of the field. Indeed, a structural understanding is essential to learning (Bruner, 1961, Herschbach, 1995, McNeil, 1999).

The term technology is even broader than Science and refers to just about everything in the designed, man-made world. Technology is manifested through abstract and concrete artifacts (Feenberg, 2002, Dasgupta, 1996). Technology is defined in terms of specific applications, such as, micro precision instrumentation. Instruction becomes integrative and interdisciplinary in scope. It is the bond with application that distinguishes technological knowledge from bodies of formal knowledge. Technological applications make use of formal knowledge but in very specific ways. The inherent interdisciplinary activity makes technology a good candidate for an integrative framework around which STEM subjects can be organized.

Engineering refers to preparation for specific occupations (Oaks, Leone and Gunn, 2001). It is in one a Science and a vocational subject. The requirements of the specific occupational field define the instructional content. Engineering makes use of formal knowledge from Science, Mathematics and Technology. The specific selection and use of knowledge, however, depends on the occupational field of engineering under study.

2.4.3 Significance of STEM Education

STEM disciplines are considered potent to the national economy. According to the National Academy of Sciences Committee on Science, Engineering and Public Policy, 2007 in United States of America, many attempts have been introduced to develop a greater number of STEM ready students. This saw increase and improvement in the availability of workers in STEM fields in government, industry, leadership and education. In 2009 the Obama Administration announced "educate to innovate" crusade to inspire and encourage students to excel in STEM disciplines (Obama, 2013). Furthermore, this initiative also addressed the insufficient number of competent teachers required to educate students in STEM subjects.

According to estimates by the National Science Foundation, nearly five million people were employed in fields such as Science, Engineering and Technology which made up about 4% of the total workforce (Obama, 2013). This was relatively a small portion of the workforce. The contribution made was crucial to the economic growth and productivity of the country's economy (Gonyea, 2017). In the context of this study, the contribution of STEM to the economy and the nation was considered paramount.

2.4.4 The Importance of Teaching STEM at Primary Level

STEM is envisaged as an important global phenomenon. As such the teaching of STEM at primary level would enhance creative education through holistic views, and arrange to integrate with prior knowledge(Manosuttririt,2016),Also active learning, problem -based everyday analogy, sequencing of concepts and creative-problem solving are fostered in school children through the teaching and learning of STEM education at primary level(Reeve,2013;Manosuttrit,2016),The STEM disciplines are distinction in our daily lives, helps us to solve the problem by creative thinking based content clarification. STEM adopts an interdisciplinary approach, it begins with a problem or an issue leads to content and skills in multiple-disciplinary subjects (Beane,1997) Interdisciplinary approach initiates with real situations that learners have to participates and solve problems through active learning. Learners construct knowledge through active in their life. In the context of this study, the importance of teaching and learning of STEM at primary level was of great interest

This section looked at the contribution of STEM to the economy of nations and its importance to the teaching and learning at primary level. Having looked at the importance of STEM the next section focusses on STEM funding.

2.4.4 STEM Funding

2.4.4.1 Funding in United States of America

In 2014, President Obama's budget proposed an investment of 3.1 billion dollars in Federal money to be spent on STEM Education initiatives, with a 6.7% increase (Obama, 2014). The investments were made to recruit and support STEM teachers as well as support STEM focused colleges and universities. More so, the budget also included funds intended for advanced research projects in Education, to understand next generation learning technologies better (Gonyea, 2018).

2.4.4.2 Funding in UK

STEM Education funding in the United Kingdom (UK) was reported to involve four independent national academies, namely: The Royal Society, the British Academy, the Royal Academy of Engineering and the Academy of Medical Sciences (Montgomery, 2018). The funding of programmes and events that inspire students to the study of STEM subjects was mentioned as a key priority. In view of the above, this study intended to establish the nature of funding and its adequacy, the Zimbabwe Government and its partners were offering to the STEM trajectory. In addition, the funding depth would give pointers to the available STEM related resources and infrastructures in teacher education colleges.

2.4.5 STEM Recognition in the Region and Internationally

2.4.5.1 STEM Recognition Ghana

Science is one of the most important subjects among others in the Ghanaian education system at all levels from primary to colleges of education. It is one of the compulsory subjects that every student needs at least a pass grade from junior high school to enter senior high school, teacher education and university (Kusi, 2017).

2.4.5.2 STEM Recognition in Malaysia

In Malaysia STEM is implemented beginning from primary schools. STEM Education is introduced earlier while in primary schools, to build perception and knowledge of STEM Education at the basic level (Nadelson, Callahan, Pyke, Hay, Dance, Fester, 2013). STEM remains vibrant in Malaysia through to tertiary education. (Mohtar, 2019).

2.4.5.3 STEM Recognition in New Zealand

In New Zealand, the standard minimum entry to gain entry to a university is any pass in a STEM subject, equivalent to the nation's national certificate of educational achievement (NCEA), plus 10 other credits in literacy and numeracy subjects (NCEA Level 3), according to Parker (2018).

2.4.5.4 STEM Recognition in Finland

Finland is a nation applauded for recruiting highly academically able initial teacher education students for the high quality of its education system. There is a multi-step process for applicants, it varies by institution but rely largely on secondary school matriculation entrance test, first base of selection, only 10% of the results proceed to next level of Vakava Examinations and take part in an interview for final selection (Parker, 2018).

2.4.5.5 STEM Recognition in Namibia

In Namibia, the minimum entry is NSSC higher level 3 or the NSSC ordinary level. A symbol must be obtained for Mathematics and Science as well as English language or a pass at least 4N5/N6 subjects with at least 40% in each, including Mathematics and a physics equivalent as well as English Language.

Given the importance of STEM knowledge, it was of interest in this study to examine the entry qualifications of prospective pre-service teachers into teacher education colleges This enhanced comparative analysis. Having looked on STEM recognition regionally and internationally, the focus is now on approaches that can be used to incorporate STEM in the primary teacher's college curriculum.

2.5 Approaches to teaching and learning of STEM subjects in the Curriculum

Three approaches for teaching STEM Education were abounding in reviewed literature. The distinction between each of these methods is rooted in the degree of STEM content used. These include silo, embedded, and integrated approach.

2.5.1 The Silo Approach

This refers to isolated instruction within each individual STEM subject (Dugger, 2010). Emphasis is placed on knowledge acquisition as opposed to technical ability (Morrison, 2006). Concentrated study of each individual subject allows the student to gain a greater depth of understanding of course content. This focused instruction stirs appreciation for the beauty of the content itself. This is how Science, Technology, Engineering and Mathematics Education has been approached in curriculum design and teaching (Roberts and Cantu, 2012). Silo STEM instruction is characterized by teacher-driven classrooms. Students are provided with little opportunity to learn by doing. Rather they are taught what to know (Morrison, 2008).

Morrison (2006) suggests the prevailing belief behind silo STEM instruction is to increase knowledge that generates judgment. An instructor operating within the confines of their discipline can develop quality instruction for students which must not be overlooked. Figure 3 depicts the silo approach.

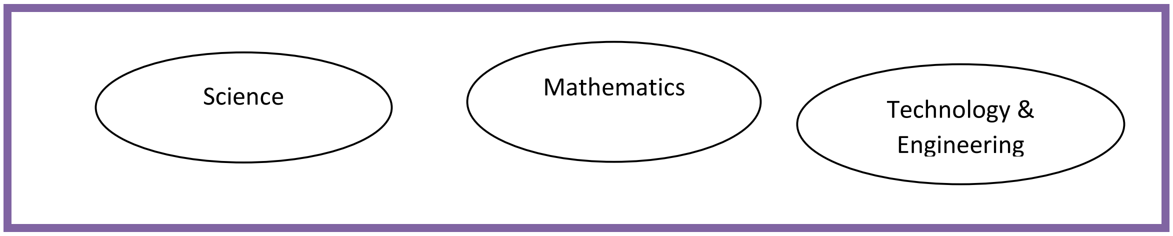

Figure 2. 3 The Silo Approach

Source: Roberts and Cantu (2012)

In Silo approach to STEM Education each circle represents a STEM discipline. The disciplines are taught separately which keeps the domain knowledge within the confines of each discipline.

2.5.2 Silo Approach Demerits

Dickstein (2010) suggests silo instruction has the propensity to isolate prospective STEM contributors to the field. It has been observed, females are less likely to participate in courses containing the word engineering within the title, for example, Civil, Mechanical and Electrical Engineering. The lack of female participants limits valuable perspectives which could enhance STEM related fields (Bour, Bursue and Kontantinidis, 2011). Secondly, it is possible silo instruction may encourage students to maintain a segregated perception of content courses. Without practice, students may fail to understand the integration which naturally occurs between STEM subjects in the real world (Breiner, Harkness, Johnson and Koeher, 2012). Finally, the silo approach can unintentionally inhibit student's academic growth. It may tempt teachers to rely on a lecture – based methodology rather than a hands-on-approach, which research indicates is more desirable for student learning (Dickstein, 2010, Deslauriers, Schelaw and Wieman, 2011). While an instructor may choose to implement a variety of teaching strategies in a silo classroom, the content would likely remain the focus of study.

2.5.3 The Embedded Approach

Embedded STEM instruction may be broadly defined as an approach to education in which domain knowledge acquired through an emphasis on real-world solutions and problem-solving techniques within social, cultural and functional contents (Chen, 2001. In practice, embedded teaching is effective instruction because it seeks to reinforce and complement materials that students learn in other classes (ITEEA, 2007). A technology education teacher uses embedded to strengthen a lesson which benefits the learner through understanding and application. In a STEM embedded approach, the technology education content is emphasized, thereby maintaining the integrity of the subject matter. Embedded differs from the silo approach in that it promotes the learning through a variety of contents (Rossouw Hacker and de Vries, 2010). Figure7 depicts the embedded approach to STEM Education.

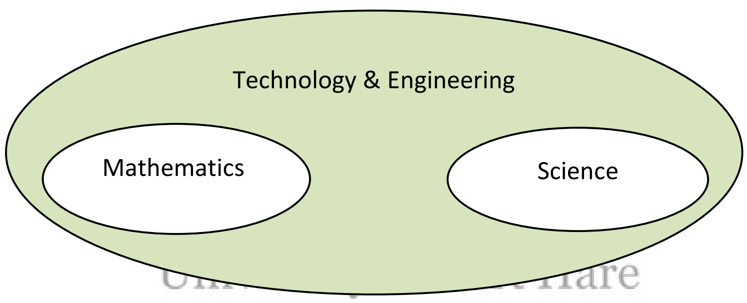

Figure 2. 4 The Embedded Approach

Source: Roberts and Cantu (2012)

In Embedded Approach to STEM Education each circle represents a STEM discipline. Domain knowledge from at least one discipline is placed within the center of another. Although embedding can be valuable instructional strategy, there are challenges that must be considered, embedded approach may lead to fragmented learning (Hmelo and Narayanan, 1995).

2.5.4 The Integrated Approach

An Integrated Approach to STEM Education envisions removing the walls between each of the STEM content areas and teaching them from one subject (Breiner et al, 2012; Morrison and Bartlett, 2009). Integration is distinct from embedding in that it evaluates and assesses specified standards or objectives from each curriculum area that has been incorporated within the lesson (Sanders,2009). Training students in this way is perceived beneficial as it is a multidisciplinary world reliant on STEM concepts which students must use to solve real world problems (Wang, Moore, Roehig and Park, 2016). Furthermore, instructing through integration develops the expectation of increased interest in STEM content areas, especially if it is begun when students are young (Barlex, 2009, Laboy – Rush, 2010). Two common approaches to integrative instruction are multidisciplinary and interdisciplinary integration (Wang et al, 2011). Wang et al., (2011) explain interdisciplinary integration begins with real-world problem. It incorporates cross-curricula content with critical thinking, problem-solving skills and knowledge to reach a conclusion. Multidisciplinary integration asks students to link content from specific subjects, but interdisciplinary integration focuses student attention on a problem and incorporates content and skills from a variety of fields. Figure 5 depicts the integrated approach.

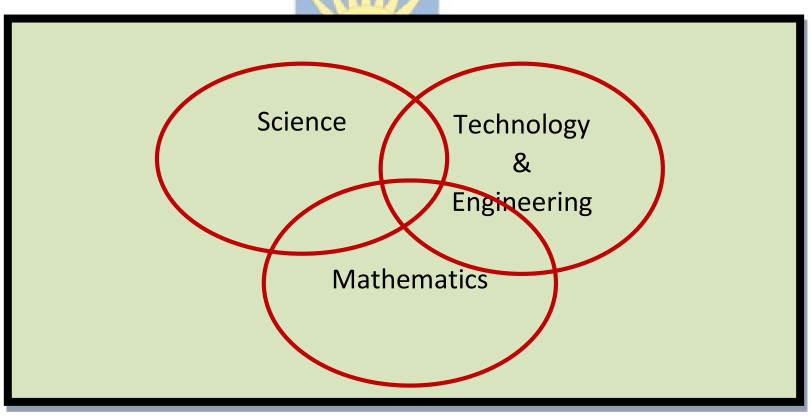

Figure 2. 5 The Integrated Approach

Source: Roberts and Cantu (2012)

The STEM content areas are taught as though they were one subject. Integration can be done with a minimum of two disciplines but is not limited to two disciplines. Proponents of STEM Education suggest integration is the best approach to STEM instruction (Laboy-Rush, 2011, Wang et al, 2011). However, it is important to remember individual STEM disciplines are based on different epistemological assumptions and integration of the STEM subjects may distract from the integrity of any individual STEM subject (William, 2011).

2.6 STEM Policies

2.6.1 STEM Policy in the United Kingdom (UK)

In the current education policy in the UK, reference to STEM Education is in the Department of Business, Energy and Industrial Strategy (BEIS). The department replaced the UK Department for Business Innovation and Skills. A policy paper was published in 2012 and updated in May 2015 entitled Public Understanding of Science and Engineering which states:

> *Science and research are major contributions to the prosperity of the UK. For our prosperity to continue, the government believes we need high levels of skills in Science, Technology, Engineering and Mathematics (STEM), and citizens that value them (Department for Business, Innovation and Skills, 2015).*

An initial analysis of the policies of the UK department of education published since 2011 show that the strategy has been segmented into regions (Department of Education, 2011). Given this segmented strategy in STEM education policy in the UK it is easy to see how challenges in translating this policy into teacher education for STEM could be generated. The segmented policy on STEM for teacher education is thus even more problematic and results in greater fragmentation of approaches and understanding (Montgomery and Fernandez-Candenas, 2018).

2.6.2 STEM Policy in Hong Kong

The STEM policy in Hong Kong was because of stakeholder consultation. The policies showed support for the promotion of STEM Education. Emphasis was put on the curriculum renewal of the Science, Technology and Mathematics, enriching learning activities and enhancing the training of teachers for strengthening STEM Education (Education Bureau, 2016). The policy was because of consultation. Consultation document entitled Promotion of STEM Education – Unleashing Potential in Innovation was released on 5 November 2015. The document and other relevant materials were accessible on the website. A 2-month consultation followed to collect feedback from various stakeholders in the education and other sectors (Education Bureau, 2016).

Resultantly, the study focused on STEM policies in United Kingdom and Hong Kong to understand how they guided STEM Education in teacher's colleges in Harare, Zimbabwe. International STEM policies were also examined to make sufficient comparative analysis.

2.7 STEM Teacher Educator's Knowledge Base

Teachers' knowledge strongly influences all aspects of teaching, such as, preparation, planning and decision making regarding the choice of content to be learnt (DeJong, Veal &Van Driel, 2002). The knowledge base for teaching is made up of seven categories which include subject matter knowledge (SMK), pedagogical content knowledge (PCK), curriculum knowledge, general pedagogical knowledge, knowledge of the learners and their characteristics, knowledge of educational contents and knowledge of educational purposes (Shulman, 1987). According to (Shulman, 1987) SMK is based on two main areas, the organization of concepts, facts, principles, theories and the nature and structures of knowledge which refer to the ways in which truth, falsehoods, validity or invalidity are established (Shulman, 1986). In other words, the teachers' SMK incorporates not only knowledge of specific topics of the curricular but also knowledge about the epistemology of Science or the nature of scientific knowledge. This implies that the teacher should also be competent on how scientific knowledge is constructed and what it entails. The scientific knowledge encompasses what science is all about which incudes, concepts, generalisations, theories, laws among others.

Therefore, one can argue that one of the most important characteristics of being good Science teacher is having a very good background of SMK. However, research studies which have attempted to find relationship between SMK and good teaching (Abell, 2007 Childs and Mcnicholl, 2007 Kincl 2009) suggest that while a good background in SMK is a pre-requisite for good teaching, it is not the only requirement. Kincl (2009) contends that high academic performance in a specialist subject is not an automatic precursor to good teaching. In fact, subject specialist is more likely to resort to teaching through a process of knowledge transmission which is not enough for deep learning to take place.

Exemplary Science teachers, as argued by Shulman (1987) also need to develop PCK which enables Science teachers to blend content and pedagogy into an understanding of how particular topics, problems or issues are organized represented and adopted to the diverse interest and abilities of learners and presented for intuition (Shulman, 1987).

Magnusson, et al (1999) describe PCK for Science teaching as the transformation of several types of knowledge not only SMK. These knowledge areas consist of five components which include orientation towards Science teaching, knowledge and beliefs about the Science curriculum and assessment in Science, knowledge about instructional strategies for teaching Science or topic specific pedagogy and knowledge about student's understanding and misconceptions of specific Science topics (Figures 6 and 7).

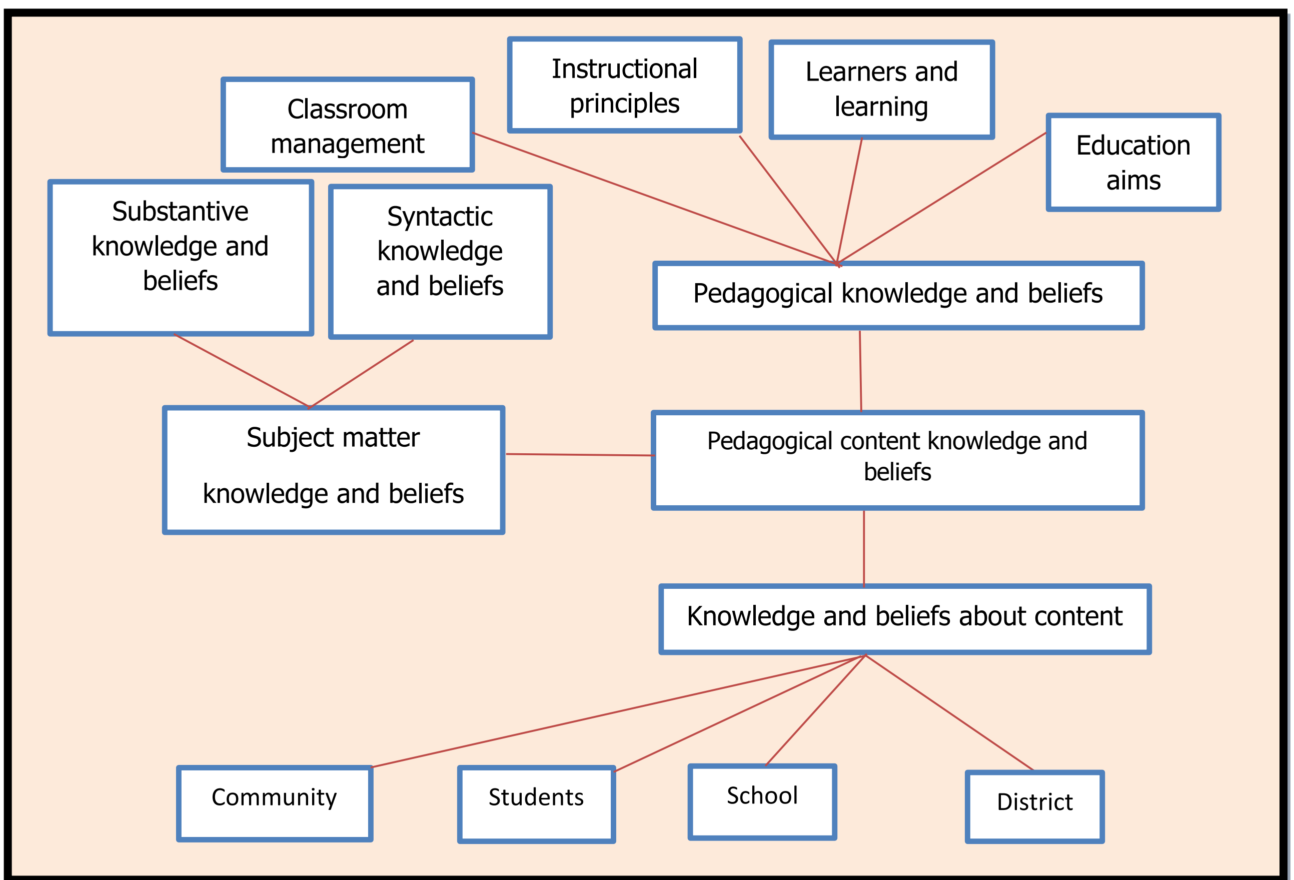

Figure 2. 6 Model of the relationships among the Domains of Teacher Knowledge

Adapted from Magnusson et al (1999 p.98)

PCK develops with teachers' experience (Abell, 2008, Davies et al, 2006) it is a cyclical process whereby teachers transform, reflect and evaluate their practice and continue to learn as they develop this practice, PCK is also content specific or subject specific knowledge that is fundamental for effective Science teaching. According to Magnusson, et al (1999) subject-specific knowledge entails general strategies applicable to teach Science.

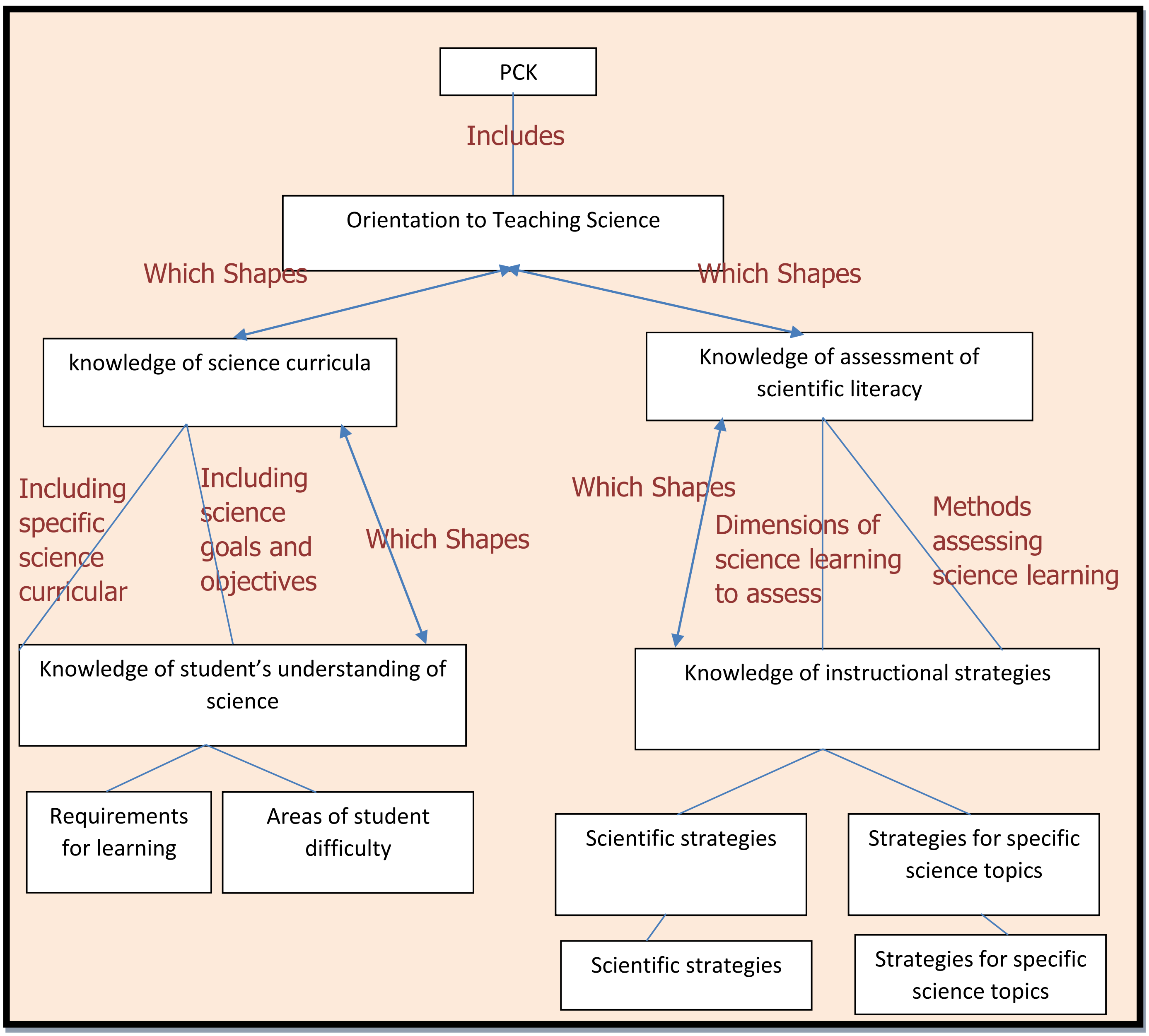

Figure 2. 7 Model of the relationships Among the Domains of Teacher Knowledge

Source: Adapted from Magnusson et al (1999 p98)

Content specific strategies such as illustrations, models, analysis, experiments and simulations are required when teaching topics within a Science field. Abell (2008) acknowledges that PCK differs from one discipline to another for example teaching Biology is different from say Chemistry.

The components of orientation to Science teaching refer to teachers' knowledge and beliefs about main domain of Science teaching at a grade level. This component embodies the teachers' general conceptualization of Science teaching (Murat,2014). This knowledge serves the teacher as a conceptual map that guide pedagogical decisions about topics, such as, daily objectives, homework content, the use of teaching material, and evaluation of student learning (Murat, 2014). According to Magnusson et al (1999) the orientation to Science teaching involves processes such as academic rigor, didactic, conceptual change, activity-inquiry and guided inquiry. Magnusson et al (1999) admit that even through some of the orientations share similar characteristics, teacher's rationale behind the instruction make the orientations distinguishable.

The second component of PCK is the knowledge and beliefs about Science curriculum. Magnusson et al (1999) held this component in two categories, mandated goals and objectives, and specific curricular programmes and materials. Magnusson et al (1999) consider curriculum knowledge as a section of PCK because they believe curriculum knowledge that distinguishes the content specialist from the pedagogue (Murat,2014). One of the sub-dimensions of the curriculum knowledge is knowledge of goals and objectives and it defined the knowledge of goals and objectives for students in the subject they are teaching besides the expression of those guidelines through the topics addressed during the education year. The other sub-dimension is knowledge of specific curricular programmes and materials that are relevant to teaching a specific topic (Murat, 2014).

Knowledge of students understanding of Science is the third component of Magnusson et al (1999), PCK model and means that teachers should have knowledge about the learners to help them develop specific scientific knowledge. This knowledge and beliefs about prerequisite knowledge for learning specific knowledge and knowledge of the abilities and skills that students might need to learn specific concepts (Murat, 2014). Teachers should also know how students varying in developmental ability levels, different learning styles. Teachers expected to know learner's individual differences and provide different opportunities to learners with different needs (Murat, 2014). Knowledge of Areas of students' difficulty in another sub-dimension and refers to teachers' knowledge of the Science concepts or topic that students find learning difficult and knowledge of the reason why students find learning difficulties. The given examples of student's difficulties were the abstract of some of the Science concepts, problem showing related difficulties, such as, solving problems and misconceptions of students (Murat, 2014).

Knowledge of assessment in Science is the fourth component of Magnusson et al (1999) PCK model, and includes two sub-dimensions, that is knowledge of dimensions of Science learning to assess and knowledge of methods of assessment. The former refers to knowledge of the aspects of students' learning that are important to assess for a particular topic as knowledge application and Science process skills etc. the latter refers to knowledge of the method that is suitable to utilize in assessment to the specific aspects of students learning which are important for particular topics, such as, paper, pencil text, portfolio, laboratory and practical examinations. Teachers are expected to be knowledgeable about the strengths and weakness of an assessment method for a special topic (Murat, 2014).

Knowledge of instructional strategies is fifth and last component of Magnusson, et al (1999) PCK model. It is composed of two sub-dimensions, namely: knowledge of subject specific strategies and knowledge of topic special strategies. These two dimensions were different in their scopes and subject specific strategies mean applications specific to Science and topic specific strategies in particular application specific to a topic or a concept.

Knowledge of subject specific strategies includes general approaches utilized during performing the Science instruction, such as, learning cycle, guided inquiry and conceptual change. Magnusson, et al (1999) asserted that the knowledge is related to orientation to teaching Science in which there are general approaches to Science instruction that are consistent with the goals of orientations. This knowledge requires that teachers should be able to describe and demonstrate a strategy and its phases in an effective way (Murat, 2014).

Knowledge of topic specific strategies is employed to help students comprehend specific Science concepts. According to Magnusson et al (1999) PCK model, this knowledge also has two categories, viz: representations and activities. Representations refer to the knowledge of techniques to represent specific concepts or principles to aid students in developing understanding, such as, analogues, models, illustrations and examples. This knowledge also contains teachers' ability to invent new representations to help students in learning a specific concept and relationships. Moreover, teachers should be aware of the relative strengths and weakness of representations. Activities, as the latter category of these components are utilized by teachers to help students comprehend specific concepts or principles, such as problems, demonstration, simulations, investigations and experiments. Teachers should be knowledgeable about the strengths and weaknesses of a particular activity the extent to present or clarify an important concept or relationship.

2.7.1 PCK empirical studies in STEM Education

Lee and Luld (2008) explored five experienced Science teachers' general PCK.in America They attempted to clarify how experienced teachers view necessary knowledge for Science teaching for more than two years, interviewing, classroom observations, lesson plans and monthly reflective summaries were employed for collecting data, interviews were conducted three times over the course of the study. In the first-round interviews, participants' background characteristics were questioned. In the second round, teachers were asked to clarify their teaching followed by their classroom instructions, and in the third-round interviews, teachers were requested to draw a diagram representing the components of PCK. Cards sorting activity was employed to elect teachers' ideas about types of knowledge that were necessary for teaching. According to the teachers, subject matter knowledge, knowledge of goals, students, teaching curriculum organization, assessments, and resources were the necessary knowledge in teaching. All the teachers agreed on the view that subject matter knowledge was the most critical one in teaching

Science. However, there were differences among the teachers with respect to their views about relating to other types of knowledge with Science teaching. Teachers claimed that their PCK developed through experience in teaching and their participation in workshops. Although they viewed knowledge necessary for teaching Science, there were differences in their representations for general PCK with respect to grouping knowledge and these interactions. Moreover, knowledge of resources was the most stated type of knowledge participants.

Ingber (2009) examined six Science teachers' PCK in planning in and outside of this expertise area in America. More specifically, teachers' planning use of resources, and use of instructional strategies were clarified. Data were collected using survey and think aloud protocols during planning. Findings demonstrated that teachers employed terminology better in their area than they did not outside of their expertise while they were planning. They were able to relate more concepts in their area than they did outside of their area. In a similar view they were more knowledgeable about the resources required for enhancing subject matter and teaching during planning a unit in expertise than they did it for a unit outside.

2.7.3 Technological Pedagogical Content Knowledge

Technological pedagogical content knowledge (TPACK) was introduced to the educational research field as a conceptual framework for understanding teacher knowledge that is required for technology integration (Mishra and Koehler, 2016) TPACK evolved from Shulman's (1986) theory of pedagogical content knowledge (PCK)and focuses on the need for teachers to skillfully demonstrate their ability to integrate technology within the confine of content and pedagogical domains. TPACK can be perceived as a teaching subject specific content with appropriate pedagogical methods and selected technologies. It is well understood that teaching is a complex cognitive activity that requires teachers to draw upon several types of knowledge (Koehler and Mishra, 2009). TPACK serves as a useful conceptual framework for thinking, analyzing, and evaluating what teachers must know to integrate technology into teaching but ultimately it must be understood as a framework for ways in which teachers might best develop this integrated knowledge (Baran et al, 2011). To date, researchers have stressed the importance of teachers having a solid conceptual understanding of the interactions that occurs among technology, pedagogy and content when planning instruction (Harris and Hofer, 2011, Koehler and Mishra, 2005) some even further elaborate on how this understanding can lead to more effective teaching in classrooms (Hughes, 2005, Neiss, 2005, Zhao, 2000). Highlighting the integrated knowledge domains (such as, TCK, TPK PCK and TPACK) provides a model that reflects the complicity of the multifaceted lens of teacher knowledge that is needed to understand and define this framework (Wong, 2016).

The TPACK framework consists of seven components as follows

- Technology knowledge (TK): Knowledge about different technology, including both low-tech and high-tech technologies
- Content knowledge (CK): Knowledge about the actual subject matter to be taught.
- Pedagogical knowledge (PK); Methods of teaching a subject matter.
- Pedagogical content knowledge (PCK): The content knowledge that deals with the teaching process (Shulman, 1986).
- Technology content knowledge (TCK): Knowledge of how technology can create new representations for specific content.
- Technological pedagogical knowledge (TPK); Knowledge of how different technologies can be used in teaching and to understand that using technology may affect how teachers teach.
- Technological pedagogical content knowledge (TPACK); Knowledge required by teachers when integrating technology into their teaching in any content subject area (Schmidt et al, 2009, p. 125).

Given the diversified views of teacher educators' knowledge base by different authors, the current study envisaged to examine whether the STEM teacher educators in teacher education colleges in the Harare Metropolitan Province are endowed with these types of knowledge. Also, when preparing pre-service STEM teachers, do STEM educators reflect that they are endowed with these different types of knowledge which all encompass their skills and competencies?

2.8 STEM Teaching and Learning Approaches

Teaching and learning approaches are an important aspect of STEM implementation. Delivery methods form the second sub-research question of this study. There are several teaching methods in the field of education. However, there are specific methods relevant to the teaching of STEM education. Some of these are problem solving, problem-based learning, curriculum-based learning, cooperative/collaborative learning, guided discovery and laboratory approach. These are articulated below:

2.8.1 Problem-Solving

Problem-solving is identified as one of the basic life functions of the natural intelligence of the brain (Polya, 1973, Zhong, Waugh and Chiew, 2010 and Tambara, 2015). Problem-solving is generally considered to be the most important cognitive activity in an everyday and professional context (Jonassen, 2000:63), and it is thus, regarded as critical in the teaching and learning of STEM (Gaigher, Rogan and Brown, 2006, Robabeh, Hassan and Farzad, 2012, Sepeng, 2011, Sepeng and Webb, 2012).

2.8.1.1 Approaches to Problem – Solving

Schroeder and Lester (1989) and Tambara (2015) distinguished three approaches to problem solving, namely: teaching about problem solving, teaching for problem solving and teaching via or through problem solving. These three approaches can be illustrated as follows (Figure 2.8):

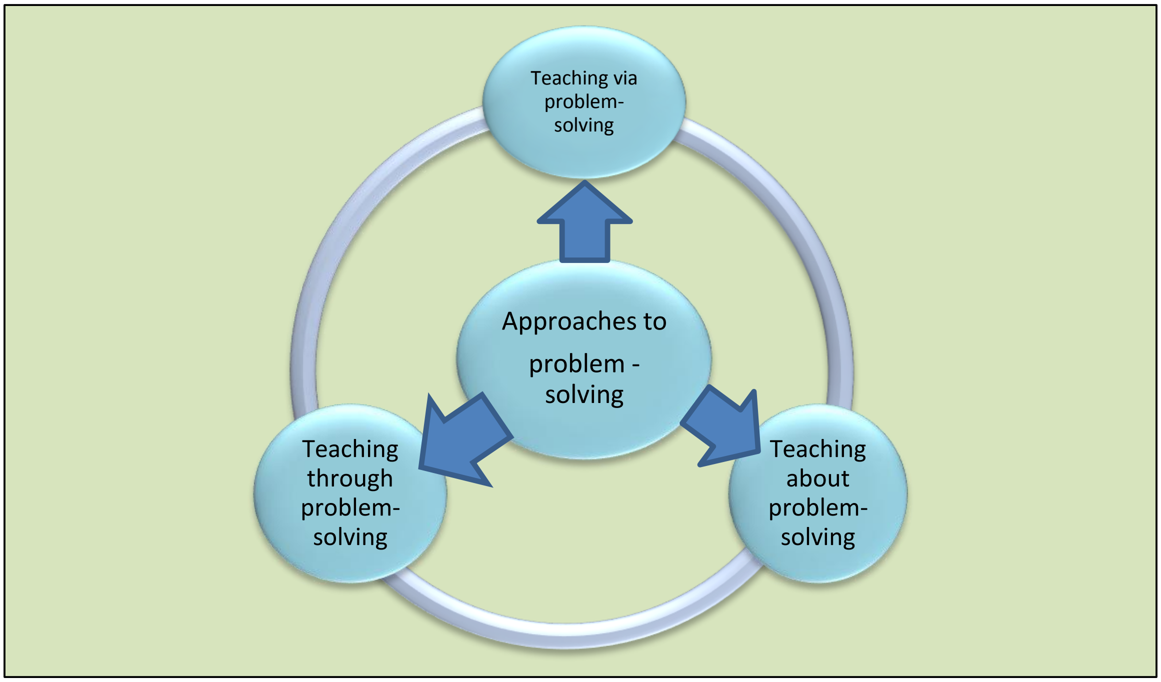

Figure 2. 8 Approaches to STEM problem-solving

Source: Adapted fromTambara, (2015)

2.8.1.2 Teaching About Problem- Solving

In teaching about problem-solving Polya's (1973) four step model is the starting point. The few phases of this model are understanding the problem, planning, carrying out the plan and reflecting on the results. The focus in teaching about problem solving is to directly teach the four problem- solving steps together with several strategies from which the learners can choose to solve the problem. This approach, however, reduces problem solving to yet another topic in the curriculum that may be taught in isolation. Teaching about problem solving does not foster learners' original thinking because learners must choose between a variety of solutions and problem solving just becomes an exercise of choosing one of the super strategies to use, (Tambara, 2015).In teaching about problem-solving, the STEM lesson also focuses on developing learners' meta-cognitive behavior. According to Ye, Doyle, Czar nacho and Baker (2011) a lesson about problem - solving consists of the following four phases:

- **Orientation phase:**

  In this phase, the teacher's principal objective is to help the learners understand the various features of the problem, including the significant information, the given circumstances, and the question.

- **Organization phase**

  In this phase, the assumption is that the majority of the learners have understood the problem and therefore, this phase the teacher tries to assist the learners in coming up with strategies that would likely lead the learners to the likely solution. As an example, the teacher might have the learners discuss different plans, and past problem-solving experiences. The objective of such activities in the orientation and organization phases is to prepare the learners for solving the problem.

- **Execution plan**

  The learners are encouraged to work in small groups or individually to implement the plan that was agreed upon in the organization phase regarding solving the problem. The teacher's task is to observe what learners are doing, to provide them with clues through questioning and to assist any groups that might have reached a stalemate. The teacher also prompts the learner' to check the corrections of their calculations and the reasonableness of their proposed solution.

- **Verification**

  This phase involves learners personally scrutinizing their solution, sharing their solution with the whole class, and providing their solution with a fitting name, thoughtful debate about the accuracy of the strategies used, and the answers given, is held.

Each lesson focuses on the development of positive attitudes and beliefs about problem solving in the learners, as well as in themselves as problem-solvers

The following are attributes of the problem-solver that contribute to success in problem-solving (Voskoglou, 2008: 13).

- **Resource**

  The conceptual understanding knowledge, facts and procedures used during problem – solving fall under this attribute.

- **Control**

  This includes the selection and implementation of resources and strategies, as well as of behaviour that determine the efficiency with which facts, techniques and strategies are exploited, including planning, monitoring, decision making, and conscious meta-cognitive acts, among others.

- **Methods**

  The general strategies that are used when making out a problem, like constructing new statements and ideas, carrying out computation and accessing resources all from part of the methods.

- **Heuristics**

  More specific procedures and approaches that are used when making out a problem using graphs, looking for counter examples and altering the given problem so that it is easier all form part of heuristics.

- **Affect**

  Attitudes include enjoyment, motivation, and interest. Beliefs self-confidence, pride, and persistence, among others. Emotions include joy, frustration, and impatience, among others and values/ethics. Therefore, when teaching for problem-solving, the teachers design their teaching towards the development of such qualities.

2.8.1.3 Teaching for Problem Solving

In teaching STEM for problem solving, or to put it in another way “an ends approach” (Lester, 2013), the focus is on the application of the acquired STEM knowledge to solve routine and non-routine problems. The teachers prepare learners to transfer the acquired knowledge to other contexts by exposing them to many instances of the STEM concept and structures under study. In this approach, learners get involved in problem solving limits the learners' thinking, as they must use the learnt algorithm and not their own thought out solution (Tambara, 2015).

Problem-solving is the instructional goal in teaching problem-solving (Wilson, Fernandez and Hadway, 2011). Anderson (2009) points out that in teaching STEM for problem – solving, the learner is required to have the following attributes (Figure 17):

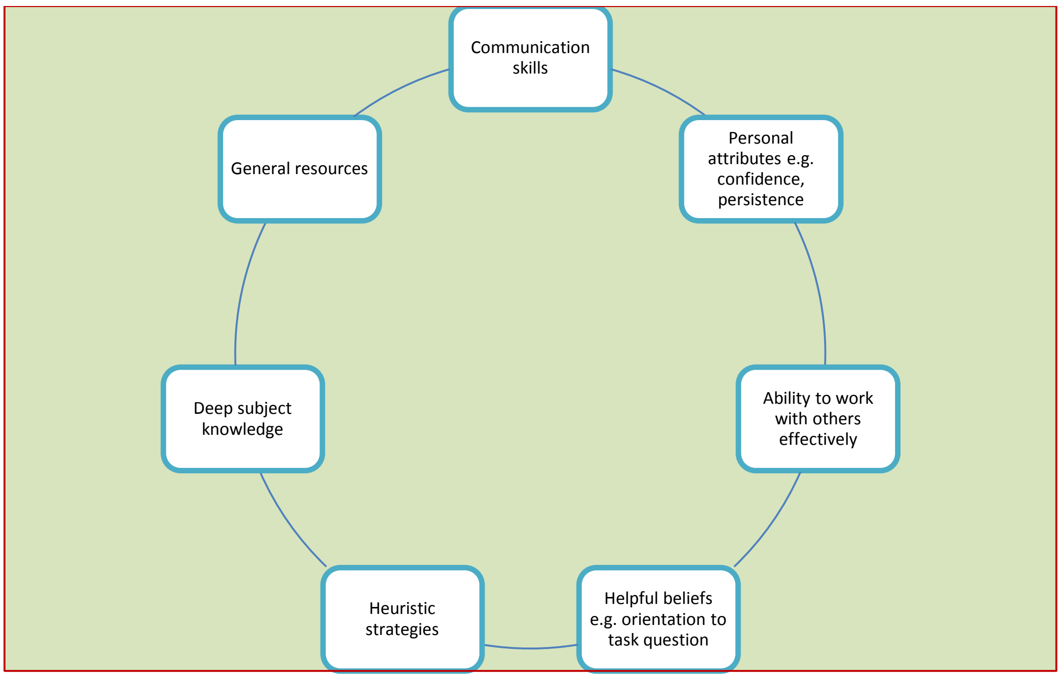

Figure 2. 9 Factors contributing to successful problem-solving (Stacey, 2005, p342).

2.8.1.4 Teaching Via or Through Problem Solving

In teaching, problem solving takes place during the process of attempting to solve problems in which relevant STEM concepts and skills are embedded (Lester and Charles, 2003. Schohen, 2003). This approach to teach via problem solving uses problems both as purpose for learning STEM and as primary means for learning.

2.8.1.5 Models of Problem – Solving

There are various problem-solving models that STEM teacher educators can make use of. The models are flexible and can alter to suit different STEM education problems. The models are design to be followed one step at a time (Tambara, 2015).

2.8.1.5.1 The Focus Model

This model is commonly used in the health profession. The model can be used to improve any process, for example, STEM Education, which spans different departments. The five steps in focus model are as follows: -

i. Find the problem
ii. Organize a team
iii. Clarify the problem
iv. Understand the problem
v. Select a solution

People often use the Focus Model in conjunction with the Plan-Do-Check- Act Cycle which allows teams to implement their solution in a controlled way.

2.8.1.5.2 The Production Thinking Model

The model can be used to solve any STEM problem creatively. It can be used by students as an individual or as a group. The six steps in the model are as follows: -

i. Ask "What is going on?"
ii. Ask "what is success?'
iii. Ask "What is the question?"
iv. Generate answers
v. Forge the solution
vi. Align resources

The advantage of the model is that it encourages one to use creative and critical thinking skills at each step of the problem-solving process. This means that one can take a well - rounded look at a problem, and that one can come up with better solutions.

2.8.1.5.3 The Six Steps of Problem-Solving Model

This model has been highly commented for being flexible and can be suitable to any STEM education problem. The steps in this problem-solving model are as follows: -

i. Define the problem
ii. Analyse the problem
iii. Identifying as many potential solutions as you can
iv. Choose the best solution
v. Plan the action
vi. Implement the solution

Polya's Four Step Model

Polya's steps are as follows:

i. Understand the problem (orientation)
ii. Plan (organization). Make a general plan and select relevant methods or appropriate heuristics for solving the problem. The learner relates their understanding of the problem step 1 to their previous knowledge
iii. Carry out the plan
    a. The learner in this step performs the computations that are required to implement the plan, and to obtain the solution to the problem.
iv. Looking back
    a. The learner reviews what they have done and checks on the correctness of their solution.

The four models briefly discussed above have much in common, although they vary in the number of steps taken as well as the wording used. The approaches are basically one and the same, in that they consist of a step- by-step approach to problem solving. The origin of these models in all cases was the study of Polya (1973). Polya who states the problem – solving step in his famous book titled 'How to solve it', was an authority on mathematical discovery, the understanding of learning and the teaching of problem solving (Tambara, 2015).

Problem Solving in Context

Examples of approaches to problem solving.

The following table illustrates how problem solving can be used in teaching mathematics under the topic subtraction.

Table 2. 2 Example Approach to Problem Solving

Content Area	**Clarification/Notes Activities/Examples**
Problem solving involving subtraction.	Solve word problems that involve subtraction up to ten. Semi concrete level. Example: there are four birds sitting on a chimney. Three birds fly away. How many birds are on the chimney now? a. Teacher says, tell me what the story is about? b. Draw a picture to show what the story is about? Learners draw pictures and symbols to explain how they found answers. Learners write the number sentences for example 5 – 4 = 1

Example of approach to problem solving (Republic of South Africa, Department of Education, 2011, pg45).

The major goal of the lesson indicated above is that learners should solve the problems concerned using the subtraction skills and concept previously learnt. The focus is on applying mathematical knowledge to solve routine or non-routine problems. The requirement that the learners have to read the problem carefully and to analyse it suggests that the focus in acquiring mathematics skills and concepts, after which they are exposed to routine problems in relation to which they are required to apply the mathematical skills and concepts concerned.

The extract also shows the teachers role as being that of helping the learners find the solution to the problem by providing an efficient strategy, namely; to understand the problem and to work out the plan which they then have to execute.
This study sought to determine the strategies used by teacher educators to develop pre-service teachers and problem solving is one such method STEM educators should employ when teaching student teachers. Problem-solving models provide relevant steps to follow when solving real life STEM problems. It is also consistent with the constructivism philosophy.

2.8.2 Problem – Based Learning (PBL)

It is a student-centered active learning in which teachers act as facilitators to guide students during the learning process (Mohtar, 2016). Problem based learning is also a teaching strategy based on experience (experiential instructional strategy) that encourages student to be active learners by engaging them in problems that are not very structured (loosely structured problems) that need situations which may encounter in the lives and where various solutions are possible (Mohtar, 2016). To get the solution, the student must interpret the problem, gather the information needed and identify the possible solutions, evaluate the possibilities and present the solution (Ahmed, 2008). This process will encourage students to think critically and creatively when they encounter problems in future. This method encourages students to develop a product as a result to the problem (Mohtar, 2016).

Problem based learning can be distinguished through five models. The five models can be used in any STEM education subject in the curriculum (Tambara, 2015). The following are the five models of problem solving: -

2.8.2.1 Models of problem - based learning (PBL)

Five models of problem- based learning can be distinguished that may be utilized depending on the subject, on the difficulty of the problem to assess, on the size of the class, on the course level, and on the available resources (Tennessee Teaching and Learning Center, 2010 and Tambara, 2015). The five models are as follows:

2.8.2.2 Medical school model

The learners are split into groups of eight to ten with one leader per group to assist in the discussion. The model is recommended mainly for upper levels, and seminar type classes. It is good for highly motivated experienced learners (Tambara, 2015).

2.8.2.3 Floating facilitator model

When using this model, the teacher educator acts as a floating facilitator, who moves from group to group to check student understanding (Tambara, 2015). The facilitator model is usually suitable to a group size of four to five students. Furthermore, in this model there is greater degree of teacher educator/facilitator input in the learning process. More so, activities within this model are group reported (Tambara, 2015). It is important to note that this model is a good choice for the less experienced learner and for classes of all sizes.

2.8.2.4 Peer Tutor Model

This model, despite being like the medical school model, uses an undergraduate peer as a tutor/leader to the group. The peer tutor helps in monitoring group progress and dynamics, as well as serving as a role model to novice learners. This model is a good choice for all class size. (Tambara, 2015).

2.8.2.5 Large Class Model

PBL can work in large classes if they are instructor-centered. In this case, the instructor acts as a discussion leader, generating questions, and guiding students in ranking learning issues, and reporting results as well as in sharing resources.

2.8.3 Advantages of PBL

The following evidence claimed for PBL provide compelling reasons for adopting the method (Norman and Schmidt, 1992, Udew 2006):

PBL facilitates the processing of new information. It leads to the activation of prior knowledge, which in turn, facilitates the processing of new information and elaboration, which enhances the use of knowledge. The activation, and elaboration which enhances the use of knowledge, and the subsequent facilitation of new knowledge, are closely linked to the key principles of constructive and collaborative learning (Barrett, 2005, Norman and Schmidt, 1992, Udew, 2006 and Tambara, 2015). PBL stimulates the transfer of knowledge as well as self – directed and lifelong learning. Learning in a PBL setting stimulates the transfer of learning/knowledge. PBL stimulates the other two advantages that are closely linked with the key philosophies of self – directed and contextual learning, which are self – directed and lifelong learning (Tambara, 2015). Learners are better positioned to transfer concepts to new problems. A strong hypothetical premise exists in respect of the thought that PBL learners might be do better new problems. There is some preliminary indication to this effect (Barrett, 2005, Norman and Schmidt; 1992, Udew, 2006 and Tambara, 2015).

PBL stimulates contextual learning. It invigorates contextual learning by increasing the transfer of concepts to new problems. This, however, does not indicate that with PBL curricular result are instantly improved.

PBL increases the retention of knowledge. There are indications that the group discussion in PBL results in the stimulation and explanation of prior knowledge, which facilitators the increased retention of knowledge (Barrett, 2005, Norman and Schmidt, 1992, Udew, 2006). Thus, PBL stimulates learners towards constructive and collaborative, process that influence learning positively.

PBL enhances SDL skills. Such learning seems to improve SDL skills. PBL learners have been observed to make more frequent use of the library to access information, and to borrow more material from the library. (Barrett, 2005, and Tambara, 2015).

PBL promotes the development of lifelong learning skills. It improves learners' lifelong learning skills. These incorporate communication and association abilities, research aptitudes, and additionally, the capacity to handle issues, and to work in group. The way that PBL challenges learners to learn through dynamic engagement with realistic problems make learners remember what they have learnt for longer. The process of experimental discovery in which the learners take part also facilitates their reflection on their own thinking and learning process. This greatly improves their understanding of a Science they are actively involved in the problem-solving process. All of the above advantages of PBL increase the growing enthusiasm of learners about PBL and serve to raise their interest in the subject matter (Barrett, 2005, Norman and Schmidt, 1992; Udew, 2006 and, Tambara, 2005).

This section reviewed literature on problem-based learning covering the value of the method to the teaching of STEM education in teacher education colleges. Several models to implement the method in STEM education were articulated. In the context of this study, the researcher intended to establish the extent to which problem-based leaning was being employed in teacher education colleges to develop pre-service teachers for STEM Education in Harare province.

2.8.4 Project-Based Learning

Project based learning or PBL is an instructional approach built upon learning activities and real tasks that have brought challenges for students to solve (Strives, 2010). PBL is generally done by groups of students working together towards a common goal. PBL teaches students not just content, but also important skills in ways student must function in society. These skills include communication and presentation skills, organization and time management skills, research and inquiry skills, self-assessment and reflection skills, group participation and leadership skills, and critical thinking (Strivers,2016).

Outlined below are characteristics of PBL:

i. Organized around a problem or challenge without a predetermined solution.
ii. Creates need to know of essential content and skills.
iii. Students design the process for reaching solution.
iv. Requires critical thinking, problem solving, collaboration, and various forms of communication.
v. Provides the opportunity for students to examine the task from different perspectives using a variety of resources.

vi. Students learn to work independently and take responsibility when they are asked to make choice.
vii. Students regularly reflect on what they are doing.
viii. A final product (not necessarily materials) is developed and evaluated for quality.
ix. The classroom has an atmosphere that tolerates error and change.
x. The teacher takes on the role of a facilitator rather than a leader.

2.8.4.1 Learning to Learn

Effective online projects encourage students to work on a problem in depth, rather than covering many topics briefly. Students also engage in learning what is needed to solve a problem or complete a project, rather when the teacher decides in predetermined curriculum.

2.8.4.2 Life-Long Learning

Web projects build learning experiences connected to the kind of learning one does through life, rather than only on school subjects. By using the real tools for intellectual work that are used in the workplace, rather than over simplified textbook techniques, students become familiar with the kinds of knowledge that exist. Finding information and people on the internet gives students the knowledge of how to go about acquiring the knowledge they may need.

2.8.4.3 Active Learning

We all learn by doing in a well-designed Web project, students work in hands-on-mode with the physical world. They gather information and data, explore, create experiment, physically manipulate things, and organize information. They have access to people and information from the real-world and they develop a closer relationship to the real-world content of problems and projects. The connections to real people, events, and problems in the world bring relevancy and connection that is immediate and involves their interest, intellect and participation.

2.8.4.4 Cooperative Learning

Cooperative learning encourages active engagement by the students in learning, and it also builds critical skills needed in today's workplace. Online projects increase the audience and opportunity for cooperative learning by involving and communicating with a wide selection of people around the world. Students work directly with people from other places and cultures, and collaborate not only with peers, but with mentors and express interest in several fields (Strivers, 2010).

The study on implementing strategies used to develop pre-service teachers for STEM education in teacher education colleges in Harare could not escape the scrutiny of project-based learning. It had to begin with understanding the characteristics and philosophy of project-based learning as a method of teaching STEM education. The process of employing project-based learning and what it entails were issues that teacher educators needed to comprehend to successfully employ the methods in STEM education.

2.8.5 Inquiry-Based Learning

Inquiry – based learning project (PIP) is the method that emphasizes on the Science skills and attitudes, high order thinking skills, creative problem solving, design and construction of the object – based technology and encourages the children to communicate and work in teams (Chee and Adnaw, 2008). There are four phases in the inquiry, namely: Inquiry, Exploration, Experimentation, and Reflection. (Chee and Adnaw (2008). In the Inquiry Phase, students look for information about issues or topics that have been identified. They search information by using various methods, such as, the internet, video, nature- walk, visit study, Science books, and so on. The students develop the new knowledge and strengthen the existing knowledge on the subject they studied or had been exploring. After receiving all the necessary information, the students will determine the suitable materials for the projects.

In the Experimentation phase, students build or develop their inventions or ideas by creating the model according to what they had planned in the exploration phase. Students demonstrate the product and answer questions that they ask in the first phase.

In the reflection phase students reflect, the learning process which they had gone through and give a view of the product or invention that they have developed. In this phase, students are asked to give their opinion, show interest, awareness, appreciation and what they want to do next (Chee and Adnaw, 2008). The inquiry is the initial phase to stimulate the curiosity of students. There are 3Es in PIP, namely: Exploring, Experimenting and Experiencing. There are also 3Cs in PIP. These are Collaborate, Create and Communicate, (Chee and Adnaw, 2008).

2.8.5.1 Guided Discovery Method

Jummai (2011) notes that 'guided discovery' was postulated by Brunner (1961). The approach enables pupils to get first- experience in getting facts, concepts, principles and process by using mental process and manipulating scientific equipment and materials. Brunner believes that a child who is exposed to the guided discoveries gets four benefits. These are:

i. An increase in intellectual attainment.
ii. A shift from extrinsic to intrinsic motivation.
iii. Learning of the discoveries is valuable to student's investigation process.
iv. Aids memory of the child. Atadoya and Onaolapo (2008) see it as mental assimilation by which the individual grasps a concept or principle resulting from physical and mental activity. In this method the teacher ensures that the students have a chance to form concepts by studying objects before leading the students to form generalizations. In guided discovery concepts formation is the main purpose (Jummai, 2011).

Guided discovery method has the following steps:

i. The teacher describes the performance expected of the student after they have learned the concept.
ii. The teacher reduces the number of samples, concepts, or attributes.
iii. Teacher provides positive and negative examples in close succession or simultaneously.
iv. Teacher assesses the learning of students.

Guided discovery method is applicable to virtually all areas of teaching. It is a method of teaching that involves observing, classifying and so forth (James 2000 & Usman, 2010).

2.8.6 Laboratory Activity Method

This is an activity performed by an individual or group of students for the purpose of making personal observations or processes related to a product or event. It has been used in teaching STEM as:

i. A means of verifying principles, laws, or theories,
ii. Practicing one or more cognitive skills such as ability to observe, classify, measure, and interpret data,
iii. To determine the relationship between causes and effects (Jummai, 2010).

Laboratory exercises are activities carried out to provide practice in designing, operating and interpreting experiments. Laboratory activity makes the student learn about the nature of Science and Technology thereby enhancing the student interest and sharpening their understanding (Atadoya and Onaolapo 2008).

Laboratory initiative has the following points as functions of developing pedagogical skills of Science students:

i. It enhances the ability of student skills to solve other problems,
ii. It affords the students opportunities to develop manipulative skills through several attempts and thrills in the laboratory,
iii. It has the potential of simulating a lifetime interest in Science in the students,

iv. It enables student to develop scientific attitude and character such as curiosity, open – mindedness, objectivity, honesty, tolerance, and rationality,
v. It gives students opportunities to gain phenomena which aid retention of information and transition such facts in another situation,
vi. Results from laboratory work sharpen the students mind and enhance the development of self-conflict needed by the teacher in the classroom during teaching and learning of Science, and
vii. It increases student ability for critical thinking, acquisition of improved understanding of basic concepts, principles, and scientific facts.

However, adequate planning and preparation in advance with proper conduct of the activity makes the laboratory to become a center for independent study, which is student – centered, activity oriented, and investigative in nature (Jummai, 2010).

Four stages of laboratory work have been identified (Jummai, 2010) which are:

i. Pre-laboratory work learning stage: It involves gathering of all necessary materials and equipment by either the teacher alone or both the teacher and students.
ii. Pre-laboratory discussion stage: Here students are made to know what the problem is, the objectives of the experiment, and safety precautions required.
iii. The laboratory session stage: The teacher outlines the stages or procedures the students will have to follow and withdraws to the background, move around to help, and assist where necessary.
iv. The Post- Laboratory work stage: Reports made by individuals or groups are submitted for discussion. Corrections are made, differences identified and explained.

In view of the foresaid, it is evident that inquiry-based learning encourages the construction of knowledge and communication of knowledge actively through election and transforming the new learnt information and quickly connect it with prior knowledge (Mohtar, 2016). Inquiry based learning is a teaching method that is the most effective when developing STEM concepts in students (Nadelson, 2012). Given its clear benefits, it was of interest for this study to examine the extent to which teacher educators, especially those teaching STEM Education, employed the scientific methods in teacher education colleges in Harare. The inquiry-based learning was assessed for its impact on STEM Education, with a view for improvement in teacher education colleges.

2.8.7 Experimental Teaching Methods in STEM Education

Experimental teaching methods are mainly characterized by conducting hands on, practical activities to investigate and analyse a phenomenon (Dune, 2016, in Katukula, 2018). Experimental teaching methods allow learners to search for explanations by asking relevant questions that lead them to an inquiry (Katukula, 2018). In experimental teaching methods, the teacher educators provide a conducive environment to learners to explore possible scientific explanation. It is an investigative method of teaching (Katukula, 2018). Learners investigate scientific problems using tools to observe, gather, analyse and interpret data as they search for solutions to real life problems. Katukula (2018) asserts that they ask questions using theories and models to explain phenomenon and ideas evaluated against alternative explanations and compare evidence. Further, experimental teaching methods allow learners to be engaged in investigating scientifically oriented questions where they learn to give priority to evidence, evaluate explanations, consider alternative explanations and learn to communicate and justify their decisions (Katukula, 2018).

The most prominent form of experimental teaching methods is guided and open inquiry (Kang and Keinor, 2018).

2.8.7.1 Unguided Inquiry

The open inquiry has minimal supervision as it starts with the learners developing questions for investigation (Katukula, 2018). When using this technique, the method of study can either be lab work, class practical, teacher demonstration or small group practical. Open inquiry replicates real life situations for the learners (Katukula, 2018). Further, there is provision of opportunities to the learners for them to apply their knowledge and skills during activities (Habok, 2016).

What experimental methods were offered in STEM education in teacher education colleges and how did student teachers and teacher educators respond to the experimental methods? Additionally, how was it useful as perceived by teacher educators and student teachers in terms of enhancing STEM delivery? These questions were of interest in this study on examining implementation strategies used by teacher educators in developing pre-service teachers for STEM in Harare.

2.8.8 Fieldwork/Outdoor Learning in STEM Education

John Dewey cited by James and Williams (2017) emphasises that outdoor learning is an essential ingredient in meaningful and comprehensive pedagogy. It is also known as fieldwork. Goulder (2012) posits that outdoor learning provides the firsthand experience of biodiversity and ecology to the learners especially those studying Biology/Life Science and Geography. Further, it facilitates the acquisition of transferable scientific process skills, such as, recording and interpretation of scientific data (Katukula, 2018).

Fieldwork motivates learners and it makes learning more meaningful to them. This point is illustrated by a study conducted by John and Williams (2017) who sought to examine the effectiveness of outdoor learning in Geography. They reported that middle school leaners perceive outdoor learning to be enjoyable and worthwhile experience because it allows them to collect real data as they learn about the environment.

Additionally, an important aspect of fieldwork learning can be found in Vygotsky's social constructivism of scaffolding. This is where capable and more competent peer provide support to the novice during a learning episode (Tracy and Morrow, 2012). Scaffolding learners from the classroom to the field and then back to the classroom results in significant and comprehensive long-term learning (James and Williams, 2017).

A more essential aspect of outdoor learning is the development of research skills. The learners apply the research skills taught in the class when they engage in outdoor learning activities (Katukula, 2018). Additionally, to building the research skills, William and James (2017) assert that it helps learners feel more involved in their disciplines.

Whereas evidence from literature and related studies point to the value or outdoor and fieldwork in teaching STEM Education, the study in part, sought to establish to what extent teacher educators used outdoor fieldwork strategy to develop pre-service teachers for STEM education in teacher education colleges in Harare. An evaluation of how that teaching method worked and contributed to the teaching of STEM Education in teacher education colleges was of great interest.

STEM education is a multidisciplinary approach, as such the teaching and learning approach advocated for STEM teaching is inquiry based. All the teaching and learning approaches articulated in this section are inquiry-based which is the main thrust of STEM education. These include problem solving, problem based learning, project based learning, experimental method, guided discovery, laboratory activity method and outdoor activities (Field trips). These are hands on teaching methods. The inquiry- based teaching and learning approaches can be applied in any classroom from ECD to university education and to any topic in the STEM curriculum.

2.9 STEM Implementation Resources, Facilities and Support Systems

Resources, facilities and support form an integral part of any teaching and learning process. This was the third sub-research question of the study. Resources and facilities are key elements in the implementation of STEM Education. These include libraries, laboratories, classrooms, lecture rooms, multi-media centers, interactive whiteboards, captured as physical institutional infrastructure. Some of these resources and facilities are herein articulated. Teaching learning materials and equipment are educational resources that aid and support teaching and learning process, for example, textbooks, models for illustration, computers and chemical solutions. Spreen and Vally (2006) in a survey of schools in South Africa, found that 80 schools had no libraries and laboratories and 78 had no computers. Most of these schools were found in urban, peri-urban and mostly rural areas. Similarly, a study in four African countries namely, Uganda, Cameroon, Tanzania and Ghana, by 'O' Connor, (2002) revealed that majority of the schools both primary and secondary had no textbooks, laboratories, chemicals, tools and equipment teaching aids, stores and offices. The study intended to establish the extent to which the Zimbabwean situation was an exception, in the identified teachers' colleges.

2.9.1 Laboratory Resources

Laboratory has been conceptualized as a room built for teaching by demonstration of theoretical phenomenon into practical terms. Ogunyiyi (2012) said there is a consensus among Science educators that the laboratory occupies a central position in Science education instruction It could be described as a place where theoretical work is made practical. Students are involved in activities such as, observing, counting, measuring, experimenting, recording and carrying out fieldwork. More so, laboratory helps to provide a forum where the learner is given the platform to question one's beliefs, ideas, statements, theoretical propositions, among others.

In addition, Nwachukwu (2000) discovered in her survey of the resources for the teaching and learning of Biology in some of the new secondary schools in Lagos that there was a general inadequacy of resources for the effective teaching Biology. To maintain and arouse the interests of students in subjects involving laboratory work, the teacher should be effectively involved to develop knowledge and facts in learners for a good performance in any examination, and life in general. Yadar (2007) opines that no course in Science and Mathematics can be considered as complete without including some practical work. The practical work ought to be carried out by individuals either in Science laboratories or in classes.Scientific practices and applications are thus rendered more meaningful. Mutsago (2016) acknowledges that, it is an established truth that an object handled impresses itself more firmly on the mind than the object merely seen from a distance or an illustration. Thus, practical work forms an important feature in any Science and Mathematics course (UNESCO, 2008)

Most schools both primary and secondary and colleges of education, in (Cameroon, Ghana, Tanzania and Uganda) lack functional laboratories due to lack of equipment and consumables. Also, colleges have no laboratories at all, and they use classrooms which do not provide suitable settings for practical work (Femsa, 2016). In some schools and colleges, equipment must always be moved in classrooms that are already overcrowded. In other schools, poor storage of chemicals had led to contamination. In any case, some countries such as Tanzania, have done away with practical's examinations altogether, and teachers, therefore, do not see the need to spend time on practical which are examined. A laboratory, therefore, does not make much difference to their teaching methods. They concentrate on lecture methods, complimented with some demonstration and explanation. Library is an essential factor in the teaching and learning process. It forms one of the most important educational services. The educational process functions in a world of books. The chief purpose of a library is to make available to the pupil at his convenience, all books, periodicals and other educational materials which are of interest and value. More so, as a resource, it occupies a central and primary place in any college system. It supports all functions of college teaching and provides service and guidance to its readers.

In view of the foregoing, the study focused on the laboratory as a key STEM resource to understand how laboratory use guides the delivery of the STEM Education in teacher education colleges in Harare province. Additionally, the study sought to establish the adequacy and functionality of laboratories in teacher education colleges.

According to Fowowe (2002) a library must be up to date and at the same time allow access to older materials. It must be properly supported financially to fund materials, services, among others. Furthermore, Ola (2002) concluded that a well- equipped library is a major facility which enhances good learning and achievement of high educational standards. Therefore, the importance of library to colleges cannot be under – estimated.

Fuller (2006) identified a college library as an instructional resource which may significantly influence student achievement. He found that effect of library size and its student's performance has been positive. Popoola (2000) discovered that library correlates with academic achievement and those colleges with well- equipped library normally maintain high academic performance. In relation, to the above Nagata (2007) conducted a paper survey and concluded that benefits of library use and learning outcomes are related and that the library contributes to this relationship. Essentially, libraries are important for the teaching and learning of STEM Education.

With this background, the study sought to assess the availability and adequacy of library resources in the delivery of STEM education. Examination of the accessibility of the library to teacher educators and more importantly to pre-service teachers was of interest in this study.

In addition, The American Federation of Teacher's (AFT) publication, Building Minds, (2006) notes that schools should be turned into appropriate environments for learning. Resultantly, in response to section 5414 of the No Child Left Behind Act on the 'health and learning impacts of environmentally unhealthy public schools building on students and teachers' a deliberate attempt was made to correct the inadequacy. The commissioned report asserted that poor environments in schools, adversely influenced the performance and attendance of students. Crook (2006) examined the relationship between the condition of the physical environment and number of students who passed the Virginia Standards of Learning (SOL) examinations and found building condition to be a predictor of student success. This study reveals the importance of environment in the success of students.

Dwam-Narcki's (2008) study of college building conditions, attendance and academic achievement, in New York City, found building conditions to be a predictor of student attendance and student achievement on standardized tests. The results were reported after controlling for other possible factors, including socio-economic status, ethnicity, and teacher quality. Classrooms are key infrastructural facilities in the college where the teaching learning process takes place. Spacious lecture room gives the teacher and student good room for instruction (Mustayo, 2016). Additionally, solid waste disposal system is important in enhancing safe and clean environment (Mustayo, 2016). Therefore, there is need for proper management of solid waste disposal in colleges because this enhances positive attitude towards personal hygiene and environments.

2.9.2 Information and Communication Technology Resources

Another important resource for teaching STEM is Information and Communication Technology (ICT). This focuses on the use of technology to support practical work (Beeta, 2001) the use of simulations and data-loggers as tools to assist in the practical investigations unique to STEM. More so, the use of digital simulation as a specific application of ICT has received much attention in STEM. It enables students to explore and investigate phenomena not possible in the classroom, for example, investigation of phenomena which are too difficult or too dangerous (using toxic chemicals), too large or small (cosmic or molecular reactions) or too fast or slow for direct observation (McFarland and Sakellarion, 2002 and Webb, 2008, Sibuyi, 2012).The use of ICT in STEM simulation has focused on the most difficult aspect of teaching and developing students' conceptual understanding of difficult STEM topics. Macfarlane and Sakellarion (2002) argue that using ICT either as a tool or as a substitute for the laboratory - based elements of an investigation can aid theoretical conceptual understanding in some topics in STEM education curriculum. Experimental studies have shown that computer simulations can be as effective as the real activity in teaching STEM subjects and concepts and improving scientific understanding across a variety of topics (Baxter and Preece, 2000, Huppert, Lomask and Lazarowith, 2002, Trindale Fiolhais and Almeida, 2002, Zacharia, 2003). Furthermore, students in ICT supported STEM classroom also benefit from the instant feedback from experiments, as well as from the chance of more independent and self – directed learning (Baggot La Velle et al, 2003). In addition, there is evidence that focusing on specific areas of difficulty in STEM and addressing those with carefully designed ICT based simulations can lead to productive learning (Webb, 2005, 2008). However, sacrificing the hands – on – aspect of learning STEM subjects is not without criticism. Simulations as a tool for practical work completely remove any mechanical manipulation of equipment thus eliminating experimental errors. Sanitized data developed by simulations may serve to reinforce misconceptions (Osborne and Hennessy, 2003, and Sibuyi, 2012).

Data loggers are another application of ICT in STEM Education practical work and called Micro – Based Laboratories or MBLS. This application allows students to collect, record and store data collected experimentally in the field or classroom for more accurate results (Webb, 2008 and Sibuyi, 2012). More so, data loggers can provide quicker and more accurate collection of data results. (Osborne and Hennessy, 2003). While reducing the mechanical aspects of practical work and allowing students to concentrate on interpreting and analyzing data (McFarland and Sakellariou, 2002 and Sibuyi, 2012).

Given the supportive contribution that information and communication technology can render the delivery of STEM Education in teacher education colleges, the study took an interest in ICT equipment and gadgets in teacher education colleges in Harare province.

2.9.3 Institutional Physical Infrastructure Support

Availability of physical infrastructure to schools is a key component to the provision of quality education (UNESCO, 2012). Research has shown that classroom is the most crucial area within the school where students spent most of their time and that overcrowding in classrooms can stifle students' activities (Kruger & Whiteman, 2001). In the same vein Ejiwale (2013) lamented use of archaic facilities in schools which do not match the demands of STEM. The Malaysia Education Blueprint (2013-2025) also indicated that one of the factors that compromise student outcomes in STEM subjects is limited infrastructure. The inadequacy of facilities to promote implementation of STEM curriculum in developed countries such as America (Ejiwale, 2013) implies that the situation could be worse in developing countries like Zimbabwe. A study by Gadzirayi et al (2016) on the status of STEM in Zimbabwe revealed that the state off education infrastructure in rural schools was deplorable. Against this backdrop it implies that schools should be have well equipped laboratories for the successful implementation of STEM curriculum, a requirement which seemed far – fetched in Zimbabwean rural schools. Research in Zimbabwe by Zvavahera (2015) revealed that 90% of schools in Mazowe District were not offering Science subjects due to unavailability of laboratories.

The study took interest in the issue of institutional physical infrastructure resource, their availability and supportive role to the STEM Education delivery as well as their compatibility with STEM Education.

2.9.4 Interactive Whiteboard

An interactive whiteboard is a touch sensitive screen that works in conjunction with a computer and a projector, (White paper, 2006). The following were observations made from the United States of America on the importance of the interactive whiteboard as a facility in teaching and learning. Solvie (2001), investigated the correlation between the use of an interactive whiteboard as a delivery tool. Her research found out that an interactive whiteboard was novel and created enthusiasm for learning on the part of the students. Students were engaged when they touched the whiteboard or manipulated text on it. In 2004 Solvie again focused her research on interactive whiteboard engagement with students. Her research found that visual display in the form of diagrams, web and pictures, as well as use of colours and shapes to highlight text prompted engagement. Therefore, the general observation from Solvie's researches indicated that whiteboards can be used in the classroom to increase student engagement during the learning.

Also, in the United Kingdom, Bush et al (2004) found that the interactive whiteboards made teaching more visual and learning more interactive and in turn encouraging greater participation from the pupils thus improving their motivation and concentration. Cox et al, (2003) highlighted the advantages teachers felt on the use of the interactive whiteboards as follows; A number of teachers indicated that the interactive nature of the whiteboard was freeing them the time-consuming task of making resources such as number cards, and again reducing their preparation time and duplication. In view of the foregoing, the study also focused on the availability of interactive whiteboard in the delivery of STEM Education in teacher education colleges. Interactive whiteboard as a supporting facility in the teaching of STEM education took the researchers interest in this study.

2.9.5 Multimedia Centers as STEM Resource

Multimedia is the field concerned with the computer-controlled integration of text, graphics, drawings, still and moving images (video), animation, audio and any other media where every type of information can be represented, stored, transmitted and processed digitally, Bhardway et al, (2015).

The following are perceived advantages of multimedia centers:

i. It increases learning efficiency,
ii. Adds interesting sounds and animated effects,
iii. It helps the user to browse and navigate easily,
iv. Enhances networking and resource sharing,
v. Provides good quality video, images, and animations,
vi. Gives freedom to its user for searching information,
vii. Creates 3D effects of object in a variety of ways,

The following are disadvantages of using multimedia:

i. It requires a lot of investment in terms of training staff and purchasing the required technology gadgets,
ii. Converting all the resources in the digital multimedia and then storing is very difficult, and
iii. It requires special software and hardware.

Research carried by Bhardway et al (2015), concluded that multimedia is the emergence and convergence of modern technology that has brought about significant changes in the field of library and information Science. It has also helped every reader to get information which he or she wants and provides links between the user and its required information. For this study, multimedia was of particular significance. Multimedia as a resource was a great influence in the delivery of STEM Education. STEM Education implementation required the use of multimedia resource by both teacher educators and student teachers. The study wanted to establish the availability and the extent to which teacher educators used multimedia for STEM delivery.

Having reviewed literature on resources, facilities and support, the current study intended to identify the availability of STEM specific resources and facilities in teacher education colleges in Harare Metropolitan Province. The study to intended establish if the resources and facilities were adequate, with specific reference to STEM Education in teacher's colleges in Harare. Furthermore, the study examined the support rendered by different stakeholders to teacher education colleges in Harare.

2.10 Challenges to Successful Teacher Preparation in STEM Education

There are many challenges that face any curriculum innovation implementation. STEM is no exception to this. This is the study's fourth sub research question. The following were some of the challenges faced by different countries, which implemented STEM education in their education system: poor preparation and shortage of qualified STEM teachers, lack of investment in teacher professional development and inspiration. Lack of support and poor content were among the challenges also identified.

2.10.1 Poor Preparation and Shortage in Supply of Qualified STEM Teachers

The quality of teacher preparation is crucial to help students reach higher academic standards. Unfortunately, many classrooms today are filled with under – prepared individuals because they would have received poor quality training or none. Many scholars have conducted research over the past two decades regarding the relationship between poor preparation of teachers in Mathematics and Science and student achievement (Rule and Hallagan, 2006, Hibpshman, 2007). This work resulted from two observations, shortage of literature to identify reliable indicators of student achievement based on global measures of teacher qualifications (Hill, Bowan and Ball, 2005) and about the components of knowledge necessary for teachers to perform successfully (Shulman, 1986). However, to most researchers, what was known about teacher competencies was insufficient to explain student achievement (Hibpshman, 2007). Such finding led various organizations, such as the National Council of Teachers of Mathematics (NCTM), the National Research Council (NRC), the National Science Teachers' Association, and the Conference Board of the Mathematical Sciences (CBMS) to publish guidelines on the preparation of programmes and certification of both elementary teachers and secondary STEM teachers.

The 2007 Academic Competitiveness Council (ACC) report indicate that "post-secondary degrees in Mathematics and physical Science have steadily decreased in recent decades as a proportion of all STEM degrees awarded. In the study conducted by Seymour and Hewitt (1997), 74% of students successfully graduating from the STEM programmes identify poor instruction as a major obstacle. According to the Monk (1994) longitudinal

Survey of American Youth found that how much a teacher knows about his subject has a positive effect on student learning. More importantly, this study found that an increase of one Mathematics course for a teacher with modest mathematical training was associated with a 1,2% increase in student achievement for high school juniors but that the addition of further courses beyond five had a diminishing effect. In addition, the author stated that the number of courses in a teacher's background had a positive effect on students' achievement in AP courses but not in remedial courses.

Posamentier and Maeroff (2011) noted that teachers who teach in STEM programme matter. The authors asserted that a typical elementary school teacher that has minimal elementary preparation in any STEM field tends to lack confidence in his/her knowledge of the subject and may bequeath his anxiety to students. In addition, the study conducted by (Goldhaber and Brewer, 1998) found that earning a subject-specific degree had a positive effect on student achievement in both Mathematics and Science. According to the recent NRC report on teacher preparation concluded that too little information is known about the preparation of Science teachers, citing a 2003 survey showing that 28 percent of the U.S. public school teachers who are teaching Science in grades 7-12 lack a minor or major in the Sciences or Science Education (Ingersoll and Perda, (2010, p.146). In an earlier study by these authors, a 2008 study showed that 40% of Mathematics classes in high-poverty secondary schools were taught by out- of- field teachers, whereas 83percent of classes are taught by teachers with Mathematics education degrees in schools that serve the fewest low-income students (Ingersoll et al, 2008).

According to the 2010 report the President's Council of Advisors on Science and Technology (PCAST), the turnover yearly in the STEM teaching force particularly in Mathematics and Science discipline could reach 25, 000. In addition, the report indicates that within the first five years of teaching, more than 40 percent of teachers decide they no longer want to teach due to lack of professional support. Since teacher turnover takes a long time, those already in classroom must undergo a great deal of professional development, in addition, novice teachers should be educated differently to become specialists in each STEM so as to synergize the efforts of two or more subject specialists. For a pool of teachers that will be dedicated to teaching in STEM fields, being equipped with deep content knowledge in STEM and strong pedagogical skills for teaching their students are two essential attributes they should possess to be able to help students achieve deep understandings of STEM for later utilization in their lives and careers. Unfortunately, not many teachers in STEM classroom possess these attributes. Curriculum for STEM teacher preparation should emphasize these two attributes. In addition, teachers should be motivated to participate in professional development to help them achieve deep STEM content knowledge and mastery of STEM pedagogy.

In a longitudinal study that was carried out by Muwanga-Zake (2000) in South Africa, regarding the extent to which Science was professionally taught in the education system, the issue of teacher in competence to implement the inquiry- based approaches one of the key findings. Also, similar findings were reported elsewhere in the literature (Mji & Makgatho, 2006.Of great concern was that even where the apparatus and facilities were available, teachers lacked the basic skills to teach using that apparatus or even assemble the apparatus kits (de Beer, 2007).

2.10.2 Lack of Investment in Teacher Professional Development

The lack of investment in the professional development of teachers for strong knowledge base has been attributed to poor student performance. As inspired teaching inspires students, new teacher needs professional development internships for clinical training following completion of initial teacher diploma or degree. The National Council on Teacher Quality reported that all but a quarter of the student-teaching practices program in 134 educational schools earned a “weak or poor rating (Sawchuck, 2011). In addition, the report also contended that too many elementary- level teachers were being prepared for graduation by colleges.

According to Hibpshman (2007) ongoing professional development activities in Mathematics and Science should be extended to improve the content knowledge and skills of elementary teachers and Mathematics and Science teachers at the middle and high school levels. Meris (2011) asserted that 'anything that dilutes those ingredients budget acts, poor teacher preparation and professional development a disregard for low – achieving students, to name three factors- will lower the chances of success'. Herrick (2011) opined that now is the time to make significant investments in Science education. Failure to implement this will lead to poor teaching methods and resourcefulness which have failed to increase the curiosity and self-guided inquires on the part of the learners (Nwanekezi et al (2010).

2.10.3 Poor Preparation and Inspiration of Students

The 2010 PCAST report concluded that too few U.S. students were proficient in STEM and that too few of those who are proficient pursue STEM fields. For example, of all ninth grade in the United States in 2001, only about 4 percent were predicated to earn college degrees in STEM fields by 2011.The loss of potential talent begins well before high school. In both Mathematics and Science, the 70% of eighth grades who lacked proficiency faced a mounting barrier as they experienced increased difficult in STEM subjects due to lack of solid foundation in basic skills such as algebra. According to this report, two recommendations would suffice to address the observed challenges. On the other hand, students must be prepared to have a strong foundation in STEM no matter what careers they peruse. Furthermore, this preparation should involve building shared skills and knowledge. On the other hand, students must be inspired so that all are motivated to learn STEM subjects so that many of them would be excited to enter STEM fields. This would be feasible through meaningful experiences that speak to student's particular interests and abilities. According to Laboy -Rush (2011), when teachers expose students early to opportunities to learn Mathematics and Science in interactive environments that develop communication and collaboration skills, students become more confident and competent in these subjects. This not only makes higher education more attainable for students but also contributes to a well – prepared society.

2.10.4 Lack of Support from School/College

The study published by the Education Alliance at Brown University stated that in order for growth to occur in the school system it is necessary that the structures and thinking on how to conduct the business of education must be altered (Unger et al, 2008). More so, it is important to ensure that education leaders are knowledgeable about STEM Education to cultivate rich STEM learning experience and expertise in their schools (Ejiwale 2013).

2.10.5 Lack of Research Collaboration Across STEM Fields

Many STEM educators have failed in their efforts to collaborate with other STEM educators that teach other STEM disciplines. This has resulted in poor skills development in giving learners adequate sense of direction and purpose for effective learning and choice of career in STEM related fields. STEM Education is an integration of many disciplines with their differences and similarities a normal approach to teaching and learning should be devised through collaboration of the educators involved. Research collaboration through cluster concept across STEM fields for integrated curriculum will enhance connectivity and information sharing among the stakeholders (Ejiwale, 2013). Therefore, all efforts should be made to foster increase in research collaboration activities among educators and partnership with the industry personnel to bridge across the traditional approach to teaching and learning in the classroom.

2.10.6 Poor Content Preparation

To attract and retain a new generation of learners, Engineering and Technology curricula need to be renovated to optimize the skills that are relevant today. More importantly, all new teaching should provide clear guidelines for all anticipated work – load and classroom activities. STEM educators and students will benefit from explicit outcomes for courses, assignments and projects. Additionally, when specific and clear outcomes are identified not only can instructors focus their instruction on specific knowledge assessment directly to the outcomes (Ejiwale, 2013).

2.10.7 Poor Content Delivery and Methods of Assessment.

According to Onuja (1987), the method of teaching determines the amount of knowledge that learners acquires. The STEM educators as a facilitator should not only be knowledgeable in the subject but should also possess the basic and necessary skills with which to impart the knowledge of the subjects to the students and learners at all levels of learning (Nwanekezi et al 2010). Furthermore, when teaching is not effective, the learners grasp little or nothing and this reflects in the future choice of career. This implies that STEM educators should endeavor to understand the available methods and teaching strategies and select them according to the demand of the lesson at hand with attention to the diverse nature of students in the classroom their learning styles and abilities (Ejiwale, 2013). Therefore, it suffices to say, that in STEM Education, one size fit all approach to teaching and learning will not work. More important, when students are engaged in STEM Education, they should be made to understand how STEM are interrelated in the application of different STEM disciplines to solve problems, how their activities are based on analysis and interpretation of evidence or prototype building, as STEM Education is a standard – based interdisciplinary discipline. As such, the methods of assessing learning outcomes should not only be based on cognitive domain. They should include affective and psychomotor domains. With this practice, learner's basic skills would be developed and their interest in STEM subjects enhanced (Nwanekezi et al, 2010).

2.10.8 Poor Condition of Classroom Laboratory Facilities

According to the article published in Education Week regarding classroom management by Kruger and Whitemore (2001), the result of the five years' research done by the University of Wisconsin asserted that classroom is the most important area within the school where students spent most of their time and that overcrowding classrooms can make facilitation of students' activities less – effective. The study affirmed that reduction of class size can result in higher achievement. Therefore, the environment of the classroom laboratory should be made conducive to learning.

As indicated by many reports STEM Education should help prepare many scientists, engineers and technologists for the future. However, inadequate facilities and lack of trained and committed teachers seem to continue to weaken STEM Education implementation at all learning levels, primary, secondary and tertiary institutions. Unfortunately, most schools' facilities used currently were constructed long time ago and the majorities were not constructed for STEM Education but for industrial arts (Ejiwale, 2012, 2013).In South Africa ,approximately 70%of schools do not have either the infrastructure or the apparatus to teach science in a manner and standard that is recommended the world over(De Beer,1993) Many tertiary institutions were not equipped with the needed structures, tools, equipment and required instructional media. De Beer (2002) reported that 32% of the Science teachers in South Africa were qualified and competent to teach the Science subject. Similar findings were reported by Muwangu-Zake (2004) and De Beer (2007). They both lamented the incompetence of the South African Science teachers. De Beer (2002) recommended that if South Africa habours its wish of increasing natural Scientists, Engineers and Science teachers, there was need to address how they learn Science within the school system.

Reviewed literature recommends that the government and school authorities should employ adequate STEM Educators for teaching and learning STEM. Furthermore, when materials are insufficient, teachers should learn to improvise (Nwanekezi et al, 2010). If changes are implemented as needed in our schools, this would enhance teachers' ability to facilitate learning activities to students, improve academic achievement and increase in state and national test score, (Ejiwale, 2012). These are some of the challenges in developing countries that are alleged to lead to STEM collapse at the implementation stage.
There is a myriad of challenges that affected the STEM initiative in different countries as reviewed above. The emerging trend observed from different countries was that teachers lacked STEM knowledge as they were poorly trained. This was further exacerbated by lack of investment in professional teacher development programmes and lack of facilities and support systems. These were the most notable challenges faced by different countries that implemented STEM Education.

Given a plethora of challenges faced by different countries in implementing STEM from the reviewed literature, the current study wanted to establish why teacher education colleges were facing challenges in implementing STEM Education in Harare. Furthermore, the study interrogated the nature of challenges being faced by teacher education colleges in implementing STEM Education in Harare.

2.11 Empirical Evidence

Dekeza (2017) carried out a study to establish views and sentiments of rural secondary school teachers on the preparedness of rural secondary schools in implementing STEM curriculum in Zaka District, in Zimbabwe. The study revealed that 90% of the participants considered rural secondary schools as ill – equipped to implement STEM curriculum. It also revealed that there were barriers to implementation of STEM, such barriers included lack of laboratories, STEM trained teachers, as well as lack of STEM scholarship for students. The study found out that there was poor infrastructure in the secondary schools for STEM teaching. The study focused on preparedness of school to implement STEM curriculum. The research differs from the present study in that it focuses on strategies that teachers' colleges are using to implement STEM Education. There is a gap in terms of the strategies that are used for the implementation of STEM Education/Curriculum which are linked to the way teachers are trained in teacher training colleges.

Gadzirayi, et al (2016) also conducted a study on the status of STEM education in Zimbabwe particularly from schools in Mashonaland Central, Mashonaland-East, Mashonaland- West, Bulawayo and Harare provinces. The study revealed that there is currently shortage of STEM teachers as the majority has opted to look for work in the diaspora and better regional destinations. Also, the study revealed that there is a general perception that students shun Science and Mathematics. Furthermore, the study revealed that the learning environment quagmire in the country. The study focused on the status of STEM Education in Zimbabwe. The stufy found out that in Zimbabwe there us inadequate STEM infrastructure. Once more, this study left a gap in terms of the strategies for implementing STEM Education that trainee teachers are equipped with during their training. More so, in another study conducted by Kyere (2016), focus was on evaluating the effectiveness of the STEM programme using hands – on – instructions. The study revealed that teacher quality through professional development is also crucial in the implementation of STEM Education. Furthermore, the study revealed that students needed to be coached by well experienced teachers who are abreast with handling hands-on-materials to effectively teach STEM subjects. The study further revealed that hands - on pedagogy has the potential to make students active learners promote a higher level of participation and motivation. The study focused on evaluation of the effectiveness of a STEM programme. Furthermore, this study left a gap in terms of the strategies for implementing STEM Education that trained teachers are equipped with during this training in colleges.

Mandina (2012) conducted a study on the challenges faced by rural schools and the remedies to challenges to improve the standards of these schools in Zimbabwe. The study adopted a descriptive research methodology. The research used questionnaire and interviews to gather information. A sample of eighty teachers and school heads was used. Twenty of these were posted to Gokwe rural secondary schools using the cluster sampling the study the researcher found various challenges to be negatively affecting the delivery of quality education. These include lack of infrastructure, poor social and economic background, limited resources and poor funding, limited career guidance. The study focused on challenges faced by rural schools in teaching STEM and the remedies to challenges. This study left a gap in terms of strategies for implementation of STEM education that pre-service teachers are equipped with during preparation in colleges

Ejiwale(2013) in the study barriers to successful implementation of STEM education in the United States of America found out that lack of hands on training for students in the schools, no or poor condition of laboratory facilities and instructional media .In most of these laboratories there are few or no apparatus to enhance proper and efficient learning. Poor content delivery is also another major setback since most of these teachers are not STEM trained and also the method of assessment is poor. The study focused on barriers to successful implementation of STEM education in the United States of America. The research differs from the present study in that it interrogates the implementation strategies that primary teachers' colleges are using to prepare pre-service teachers for STEM education. There is a gap in terms of the strategies used by teachers' colleges to prepare pre-service teachers for STEM education.

2.12 Summary

The chapter discussed concepts and theories upon which the study was based. Constructivism and Grayson Theory of Curriculum Implementation formed the basal theoretical framework of the study. The theories have a strong bearing on the teaching and learning approaches of STEM education. The theories give divergent views of teaching and learning approaches and how STEM education could be implemented in primary teachers' colleges in Zimbabwe. Additionally, it was stressed that STEM education must systematically and critically implemented. Arrays of teaching and learning approaches that impact on the teaching of STEM in any teacher education programme were also examined. These include problem solving, problem- based learning, inquiry - based learning, guided discovery, experimental method field trips or outdoor learning. Also, teacher competence factors entry qualifications, resources, facilities and support system that enhanced the implementation of STEM education and challenges faced in implementing STEM Education were interrogated. The next chapter examines the research methodology for the study.

CHAPTER 3
RESEARCH METHODOLOGY

3.0 Introduction

This chapter presents the research methodology used in the study. In addition, the chapter gives justification of the research methodology chosen by the researcher. According to Bogdan and Biklen (2007), methodology is the strategy or the plan of action that links strategies to outcomes and governs the choice of strategies. The chapter begins with a description and justification of pragmatism as the research paradigm, which this study was located then moves on to discuss mixed method, and the research approach, which is informed by pragmatism. Thereafter, examination is made of the research design, population, sample and sampling procedures, data collection instruments, data analysis procedure and validation of research instruments. The chapter ends with a discussion of ethical issues pertinent to the study.

3.1 Research Paradigm

According to Mertens (2005, p.7) a paradigm is a way of looking at the world. It is composed of certain philosophical assumptions that guide and direct thinking and action. More so, Newman (2006, p.81) observes a paradigm as, “a general organizing framework for theory and research that includes basic assumptions, key issues, models of quality research and methods for seeking answers.” Furthermore, Denzin and Lincolin (2008) view a paradigm as a net which holds the researcher’s epistemological, ontological and methodological premises. They observe that it is guided by the researcher’s set beliefs and feelings about the world and how it should be understood and studied. Therefore, the above view reflects that it is up to the researcher to use a paradigm that suits his/her worldview or beliefs on how knowledge is created and how truth is recognized.

There are different paradigms which differ in terms of their underlying philosophical assumptions. According to Denzin and Lincolin (2008), a particular paradigm determines the scope of the necessary philosophical grounding of any study. This is because a paradigm subsumes the ontological, epistemological and methodological dimensions of a particular research effort. Pragmatism is conceived as an all-encompassing philosophy upon which an investigation is underpinned drawn from these dimensions, ontology, epistemology and methodology (Shumba, 2011) Every paradigm is based upon its own ontological, epistemological and methodological assumptions (Scotland, 2012). Ontology is the search for essence of reality or being, while epistemology is about the course, nature, possibility and limits of knowledge (Cohen, Manion and Morrison, 2007). Methodology focuses on how the research study should be planned, structured and executed to gain knowledge. Scotland (2012) in Amakiri and Eke (2018) observes that methodology asks questions on how the researcher can go about finding out whatever he or she believes can be known.

3.1.1 The Concepts of Ontology, Epistemology and Methodology

Mertens (2005) summarizes these dimensions by posing questions that the dimensions ask. Mertens, (2005, p.8) posits that ontology asks the question "What is the nature of reality?" Epistemology, on one end, asks the question "What is the nature of knowledge and the relationships between the knower and the would be known." Methodology is said to ask the question "How can the knower go about obtaining the desired knowledge and understanding?" Amakiri and Eke, (2018) underscores that once the researcher provides answers to ontology, epistemology and methodology, he has some guidance on the choice of the research design to be adopted, the research approach, as well as, the research strategy, and methods of data collection and analysis.

3.1.1.1 Ontology

Ontology is a philosophical pattern of view. It is the Science of study that deals with the nature of reality (Amakiri and Eke, 2008). Ontology is a belief system that mirrors the way an individual interprets what represents a fact. Furthermore, it is concerned with the central question of whether social entities need to be perceived as objective or subjective (Amakiri and Eke 2018). This view is consistent with the opinion of Brymen (2006) who opines that ontology is concerned with the nature of social entities. Therefore, it implies that ontology describes the researcher's view of the nature of reality.

3.1.1.2 Epistemology

Epistemology can be defined as the relationship between the researcher and the reality or how this reality is captured or known (Carson et al, 2001, in Amakiri and Eke, 2018). More so, epistemology is concerned with the questions of "what do you know?" and "How do you know it?" Epistemology is, therefore, the study of the nature of knowing. According to Tennis (2008), epistemology is the claim on what knowledge is valid in research and what constitutes acceptable sources of evidence. The empirical evidence should add value to presenting knowledge and acceptable results or knowledge findings. To make it clear, Scotland (2012) opines that epistemology is concerned with the nature and forms of knowledge. In other words, epistemological assumptions are concerned with how knowledge can be created, acquired and communicated.

3.1.1.3 Methodology

Methodology is the strategy or the plan of action that links strategies to outcomes and governs the choice of strategies (Bogdan and Biklen, 2007). It should be observed that the method of research is inevitably linked to ontological and epistemological positions. Ontology and epistemology are the foundations upon which a researcher must build his research as they shape the approach to theory and methods. Furthermore, it has been said that the positions researchers take in these matters are like a skin not a sweater, as they cannot be put on or taken off whenever the researcher sees fit (Amakiri and Eke, 2018).

Table 3. 1 Comparison of the Research Paradigms

Paradigm	Ontology	Epistemology	Methodology
Positivism	- Stable, external reality. - Law like testing.	- Objective - Detached observer.	- Experimental. - Quantitative - Hypothesis

Interpretivism	Internal reality of subjective experience	- Empathetic observer - Subjectivity	- Interactional - Interpretation - Qualitative

Source: Creswell (2014)

3.1.2 Positivism

Positivist ontology believes that the world is stable and external (Carson et al, 2001, in Amakiri and Eke, 2018). Positivists believe on a single objective reality to any research phenomenon or situation regardless of the researcher's perspective or belief (Amakiri and Eke, 2018). Positivist ontology believes that reality is always a result of cause and effect relationship (Lincolin, Lynham and Guba, 2011). Positivist epistemology is objective. Knowledge is generated through experimental methods. As such, empirical evidence can be quantified. Thus, positivists take a controlled and structured approach in conducting research by identifying a clear research topic, constructing appropriate hypotheses and adopting a suitable research methodology (Churchill, 1996; Carson et al, 2001 in Amakiri and Eke, 2018). Positivism shortcomings are that it measures independent facts about a single reality. The description of reality is mere inferences and cannot be separated from the individual noticing the observations. It is based on these inadequacies that the researcher found it skeptical to locate this study in the positivism paradigm. The study sought to investigate different perceptions from diverse stakeholders in their different social settings. Resultantly, positivism would not have provided appropriate environment as it is a closed system of thinking.

3.1.3 Interpretivism

Interpretivists hold the view that the researcher and the societal phenomenon under study are mutually interrelated and dependent (Hudson and Ozanne, 1998, in Amakiri and Eke, 2018). Interpretivists believe that knowledge is internal to the individual and subjective. They assume that truth is contextual as it depends on place and time. Interpretivists believe that reality is socially constructed and that it changes with time. The major inadequacy of interpretivism is that an individual is subject to their prejudices, opinions and perspectives and only recognizes that human interests and values drive Science.

These shortcomings led the researcher not to adopt it as an appropriate paradigm which this study could have been based. The paradigm this study was underpinned on was pragmatism. The research paradigm taps on the strength of both empirical data and sentiments from the respondents.

3.1.4 Pragmatism Paradigm

3.1.4.1 Ontological, epistemological and methodological perspectives of pragmatism

Pragmatism as a research paradigm finds its philosophical background in the historical contributions of the philosophy of pragmatism (Maxcey, 2003). It embraces plurality of methods. As a philosophical movement, pragmatism originated in the late 19thCentury in the United States (Maxcey, 2003). It is considered an American philosophical doctrine traced back to a discussion group in Cambridge, Massachusetts in the early 1870s. The group brought together the founding fathers of pragmatism, such as, philosopher Charles Sanders Pierce, Psychologist William James, Philosopher and Mathematician Chauncey Wright, Jurister Oliver Wendel Holmes Jr. and Philosopher and lawyer Nicholas St Jones Green, Philosopher, Educationist, and Social Reformer John Dewey, Philosopher, Sociologist and Psychologist George Herbert Mead, Philosopher and Political Scientist Arthur F. Bentley, and countless other academics and non-academics who further developed the doctrine over the past century (Kaushik and Walsh, 2019;Maxcey, 2003; Morgan, 2014, Pansiri, 2005, Ormerod, 2006). These scholars were known over the rejection of traditional assumptions about the nature of reality, knowledge and enquiry. The pragmatist scholars completely rejected the notion that social Science enquiry can access the reality solely by using a single scientific method (Maxcey, 2003).

Pragmatism as a research paradigm refuses to get involved in the contentious metaphysical concepts such as truth as reality (Kaushik and Walsh, 2019). It concurs that an empirical enquiry is prone to both single or multiple realities (Creswell and Clark, 2011). Pragmatist offered the opinion that there is an objective reality that can exist apart from human experience. However, they concede that this reality is grounded in the environment and can only be encountered through human experience (Coles and

Hirschleim, 2000; Morgan, 2014; Tashakkori and Teddlie, 2008). The pragmatist philosophy is underpinned on that knowledge and reality are based on beliefs and habits that are socially constructed (Yefimor, 2004). Pragmatists generally agree that all knowledge is socially constructed but some versions of those social constructions match individual's experiences more than others (Morgan, 2014).

Pragmatists view reality as a normative concept and maintain that reality is what works (Kaushik and Walsh, 2019). They argue that knowledge claims cannot be totally abstracted from contingent beliefs, habits and experience (Kaushik and Walsh, 2019). For pragmatists, reality is true as far as it helps humanity to get into satisfactory relations with other parts of life experiences (James, 2000).

As a research paradigm, pragmatism orients itself towards solving practical problems in the real world. It emerged as a method of enquiry for more practical minded researchers (Creswell and Clark, 2011; Maxcey, 2003; Rorty, 2000). For pragmatists, an enquiry in social life research is effective only if it achieves its purpose (Hothersal, 2019). Pragmatism rejects traditional philosophical dualism of objectivity and subjectivity (Bista, 2010) and allows the researcher to abandon forced dichotomies which are post-positivism and constructivism (Creswell and Clark, 2011). In pragmatism, empirical evidence is preferred over idealistic or rationalistic approaches (Frega, 2011). Rather than assigning post-positivism and constructivism in two different ontological and epistemological camps, pragmatism asks the researcher to focus on the two different approaches to enquire (Morgan, 2014).

There are arguments that pragmatism should focus on methodology, as methodology is an area that connects abstract philosophical issues to actual mechanical methods. (Kaushik and Walsh, 2019). It has been argued that pragmatists researchers should study both methodology, which is related to research itself and epistemology, which are the warranted beliefs that influence how we conduct our research (Kaushik and Walsh, 2019). It is important to focus on methodology as a tool to connect our thoughts about the nature of knowledge from our efforts to develop it rather than separating philosophical threads from the research design (Morgan, 2014). However, pragmatists argue that one important strategy for enquiry would be employing multiple methods, measures, researchers and perspectives (Patton, 2002). It has been established that, as a paradigm, pragmatism assumes an independence of methods (Greene and Caracelli, 2003; Teddlie and Tashakkori, 2009) in which researchers do not have to absolutely commit themselves to a particular research method. As a result, studies employ diverse methodological combinations to address the research questions (Patton, 2002). Many studies even employ intermixing of qualitative and quantitative data to address their research questions (Patton, 2002). For pragmatism, the best method is the one that is most effective in producing the desired consequences of the enquiry, whether it is a single method, multiple methods or a mix of methods (Tashakkori and Teddlie, 2008).

The researcher settled for pragmatism in this study because of the nature of the problem. Implementing the strategies used by teachers' colleges to develop pre-service teachers, call for divergent support and strategies. It was necessary to view it from diverse lenses and multiple data sources. This was further complimented by the fact that since pragmatism uses both qualitative and quantitative methodologies, this meant that the research would provide a clear understanding of the data (Bryman, 2006 and Creswell 2014). Furthermore, the utilization of diverse methods was relevant to this study in the sense that the researcher wanted to gather diverse evidence. This agreed with many scholars who maintain that pragmatism provides philosophical foundation for Social Science research and mixed method research (Morgan, 2014). The use of qualitative and quantitative research reduced subjectivity and weakened associated or inherent methods. Pragmatism was utilised in this study because it placed the research problem at the center (Creswell, 2003).

3.2 Research Approach

Research approach denotes ways of thinking about doing research. Trochin (2006) gives an analog of mortar that binds all major components of the research process, that is, from the research paradigm to research findings. Ivankova, Creswell and Plano Clark (2012) hold the view that there are approaches for the procedures for conducting research namely: quantitative, qualitative and mixed methods. This study made use of the mixed methods research approach dictated by the adoption of the pragmatist stance. Pragmatism considers Mixed Methods Research as the third major research besides quantitative research and qualitative research (Collins, Onwugbusie and Sulton,2006)

3.2.1 Quantitative Research Approach

Quantitative research is regarded as deductive approach (Rovai, et al 2014). A quantitative researcher regards the world as being outside of themselves and that there is '--- an objective reality independent of any observations (Rovai et al, 2014 p4)' They believe that by subdividing this reality into smaller manageable pieces, for the purpose of study, that reality can be understood (Amakiri and Eke, 2019). It is within these smaller subdivisions that observations can be made and that hypothesis can be tested and redeveloped with regard to the exemplified within the specific hypothesis which is then put to the test, conclusions can then be drawn with regard to this hypothesis, following a series of observation and analysis of data (Rovai et al, 2014). A major feature of this approach towards research is that the collection and analysis of information is conducted using mathematically based methods (Amakiri and Eke, 2014) which focus on gathering numerical data and generalizing it across groups of people (Babbie, 2010).

3.2.2 Qualitative Research Approach

Qualitative research places emphasis upon exploring and understanding '--- the meaning of individuals or groups ascribed to a social or human problem (Creswell, 2014, p4 echoed by Holiday, 2007). Additionally, Denzin and Lincoln (2008) describe this approach as gaining a perspective of issues from investigating them to their own specific context and the meaning that individuals bring to them. The major thrust is upon drawing meaning from the experiences and opinions of participants (Merriam, 2009). Qualitative methods are usually described as inductive, with underlying assumptions being that reality is a social construct, that the variables are difficult to measure, complex and interwoven and that data collected will consist of an insider's view point (Rovai et al, 2014). Rovai et al (2014), p4 make the point that this approach towards research '--- values individuality, culture and social justice which provides a content and context rich breadth of information which, although subjective in nature is current'.

This study did not adopt quantitative and qualitative as standalone approaches, rather it opted for mixed methods approach. The mixed method approach was seen appropriate and suitable to gain comprehensive understanding of implementing strategies used by teacher education colleges. Mixed methods capitalized on the strength of both qualitative and quantitative research approach.

3.2.3 Mixed Methods Approach

The mixed methods research methodology or approach fits into the pragmatic paradigm which has practical consequences. It is also pragmatic because it makes use of inductive and deductive strategies to achieve understanding and explanation (Johnson and Owngbuzie, 2004, p.14). Furthermore, Zohrabi (2013) acknowledges that the mixed methods approach has recently risen to prominence because more researchers have realized that both qualitative and quantitative data can be collected, analysed and interpreted simultaneously in a single study. Similarly, Turner (2007) holds the view that mixed methods research is becoming increasingly articulated and attached to research practice as it is now being recognized as the third major research approach, together with qualitative and quantitative research. According to Johnson and Ownegbuzie (2004, p.17), mixed methods research is the class of research where the researcher mixes or combines qualitative and quantitative research techniques, methods, approaches, concepts or language into a single study.

In this study qualitative and quantitative had equal weighting. The study was purely mixed research, quantitative and qualitative data were simultaneously collected in mixed research, data are collected concurrently or sequentially (Creswell, 2014 and Amakiri and Eke, 2019). Tashakkori and Teddlie (2003) assert that concurrent data collection demands that data are collected at the same time or simultaneously. Sequential data collection implies that the researcher collects both qualitative and quantitative in phases or sequence (Amakiri and Eke 2019). The researcher collected quantitative and qualitative data using schedules, focus group discussions, semi- structured questionnaires and document review. The choice of the multiple research instruments was drawn from the nature of the research question: what strategies are used by teachers' colleges to prepare pre-service teachers for science, technology, engineering and mathematics education in Harare metropolitan province in Zimbabwe? This was on the understanding that the research problem was a determinant of the researcher's choice of mixing qualitative and quantitative research procedures in a study (Creswell, 2014). Table 3 juxtaposes the study's sub research question with the research instruments.

Table 3. 2 Research Questions and Data collection Instruments juxtaposition

RESEARCH QUESTION	DATA COLLECTION INSTRUMENTS
[a] How competent and skilled were college lecturers in preparing pre- service primary STEM teachers?	-Semi -structured questionnaire - Focus group discussion - Interview schedule - Document review
[b] Which teaching and learning approaches were used to prepare pre-service primary STEM teachers?	-Semi -structured questionnaire - Focus group discussion - Interview schedule - Document review
[c] What resource facilities, and support systems were available in the teacher's colleges to prepare pre-service primary STEM teachers?	-Semi -structured questionnaire - Focus group discussion - Interview schedule - Document review
[d] Why were teacher's colleges facing challenges in implementing strategies for preparing pre-service primary STEM teachers	-Semi -structured questionnaire - Focus group discussion - Interview schedule - Document review

Source: Adapted from Maphosa (2010) and Banda (2016)

Furthermore, the researcher collected and analysed both qualitative and quantitative data simultaneously and rigorous in a manner which integrated the two forms of data. The nature of the research problem, implementing strategies to develop pre-service teachers for STEM education determined the use of mixed methods approach.

3.2.3.1 Advantages of Mixed methods

Greene (2007, p xiii) believes that this approach provides researchers with opportunities to "--- compensate for inherent method weaknesses on inherent method strength and offset inevitable buyers. Furthermore, Creswell and Plano Clark (2011) opine that this approach enables a greater degree of understanding to be formulated than if a single approach were adopted to specific study. More so, in this study, triangulation provides opportunities for convergence and corroboration of results that are derived from different research methods, complementarities seek elaboration, enhancement, illustration, clarification of the results from one method with the results from another (Greene, 2007 in Amakiri and Eke 2019). In this study, development utilize the results from one method to inform another method which covered all aspects of the enquiry. This study utilised initiation which involved the discoveries of contradictions or inconsistencies within the data sets which resulted in the reformation of questions or additional questions being raised (Amakiri and Eke 2019).

3.2.3.2 Weaknesses of Mixed Methods

There are several weaknesses in using mixed methods. The researcher's skill is critical. The researcher must be aware of their skills sets and whether they are able to cope with the demands of utilizing a mixed method approach (Creswell and Plano Clark, 2011). According to Amakiri and Eke, (2019) the second challenge and most pressing is that of deciding which mixed method research design is most appropriate for a particular study. Further challenges are that of time and resources in convincing others of its value (Creswell and Plano Clark, 2011). That having been said, the researcher managed the challenges through engaging in thorough planning and preparation, through setting timelines.

3.2.3.3 The rationale for the mixed method approach to this study

The mixed method approach was chosen to facilitate a better understanding of the phenomenon under study. Implementing strategies used by teacher education colleges to develop pre-service teachers for STEM education. The use of quantitative and qualitative approaches enhanced clarity of the research problem than when either approach would have been used alone (Denzin and Lincolin, 2013, Creswell 2014). Quantitative and qualitative approaches solicited for more information on how teacher educators used strategies to develop pre-service teachers. Quantitative approach ensured breadth of the study through self-administered questionnaires by the researcher. The depth of the study was enhanced through qualitative approach using face to face, semi-structured interviews, focus group discussions with teacher educators, university lecturers, student teachers and directors. Qualitative research reaches beyond the what, where and when of quantitative analysis, to investigate the why and how behind the human behaviour and the reasons that govern such behaviour (Merriam and Teddlie, 2016). More so, document review enriched the understanding of strategies of implementing STEM. Also, words and narratives of teacher educators, pre-service teachers, university lecturers and directors added meaning to quantitative numerical data. This enhanced the production of a holistic set of knowledge in this study. The study used mixed methods approach to understand more about the research problem (Amkari and Eke, 2019), how strategies of implementing STEM Education occur in teacher education colleges. Mixed methods use triangulation of data from different sources and perspectives. For this reason, the mixed method approach was used.

3.3 Research Design

According to Bless, Higson-Smith and Kagee (2006, p. 71) research design refers to 'operations to be performed to test a specific hypothesis under a given condition.' Furthermore, Welman, Kruger and Mitchell (2009, p.46) define research design as 'the plan, according to which the respondents of a proposed data collection or generation. 'Balrie and Mouton (2008) sum it up as the blueprint or plan for conducting research. Therefore, a research design is a detailed plan according to which research is undertaken. More so, its main function is to enable the researcher to move from underlying philosophical assumptions to making appropriate research decisions in terms of selecting respondents, data collection and data analysis techniques. The research problem is the one that determined the research methods and procedures, the sampling, data collection and data analysis to be used by the researcher (Zikmund, Babin, Carr and Griffin, 2010). The mixed methods research approach has various designs; these are convergent, parallel design, exploratory sequential design, embedded design and concurrent triangulation design.

3.3.1 Convergent Parallel Design

According to Creswell (2018) convergent parallel design is when the researcher collects both quantitative and qualitative data, analyses them separately and then compares the results to see if the findings confirm or disconfirm each.

3.3.2 Exploratory Sequential Design

Exploratory sequential design is characterized by a two- phase process in which the quantitative data is collected in the first phase and analysed. The results are then used to plan the second research cycle which is qualitative. Therefore, the qualitative study depends on quantitative results (Creswell and Plano Clark, 2011). Below is an example of how exploratory design is undertaken:

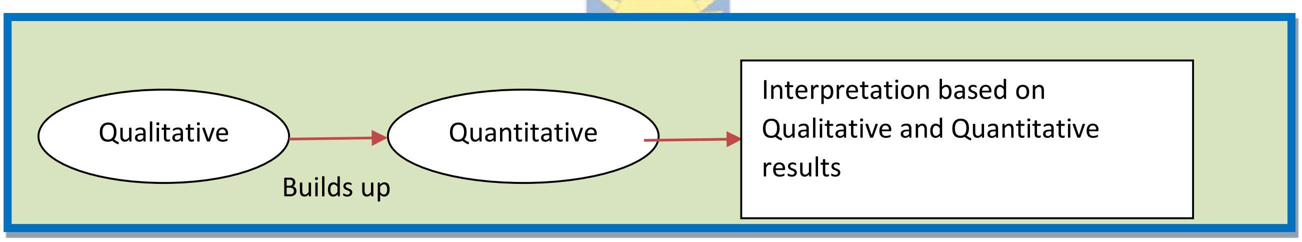

Figure 3. 1 The exploratory mixed methods design

Source: Kaushik and Walsh (2019

3.3.3 Embedded Design

Embedded design involves the embedding of qualitative methodology depending on the purpose of the research (Creswell, 2018). Embedded design can take the forms illustrated in Figure 11.

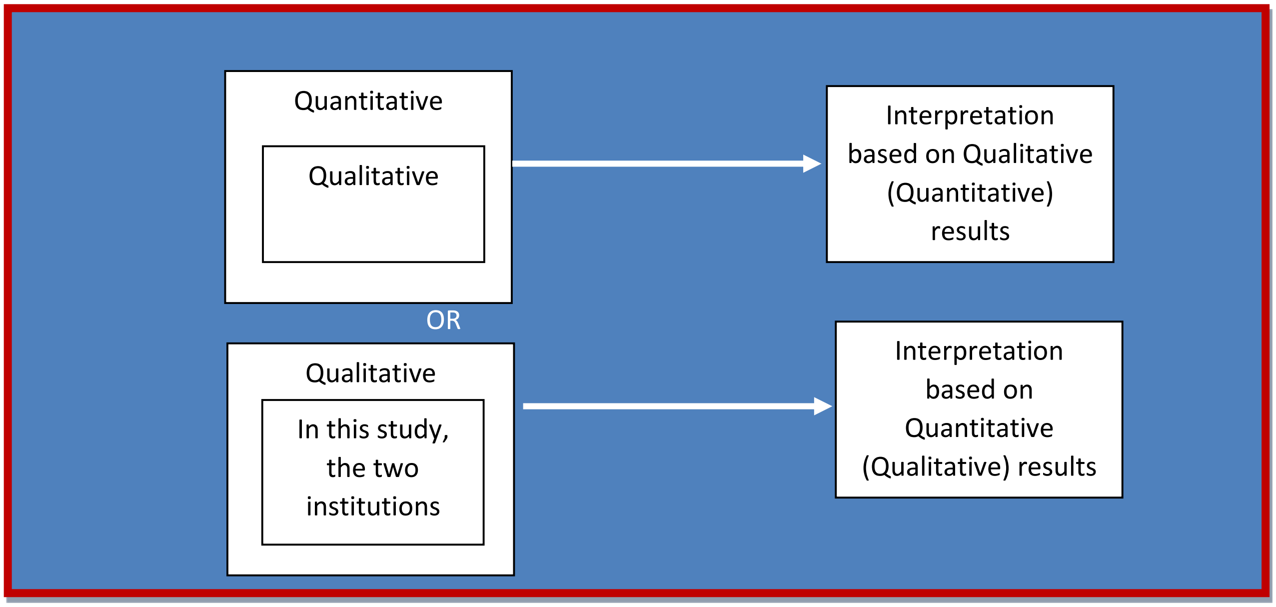

Figure 3. 2 Embedded Design

Source: Kaushik and Walsh (2019)

3.3.4 Concurrent Triangulation

Bogdan and Biklen (2007) define it as the application of several research methods in studying a phenomenon. Triangulation cross-checks data from multiple sources in search for regularities in the research data. Triangulation ensures that inadequacies associated with a single method are overcome in this study, the two institutions were considered because of their long-established initial teacher training history in Zimbabwe. The targeted teacher educators or lecturers and final year student teachers were considered to have the ability to answer questions that required description and interpretation of the phenomenon under investigation. As such the fact that no one data source can adequately describe or interpret what is happening in any situation, it was underscored that multiple data sources were used in this study. These included semi-structured questionnaires, semi- structured interview schedules, focus group interviews, and lecture teaching programmes, STEM lecture notes, and external assessment reports

Concurrent triangulation design is where the researcher uses both qualitative and quantitative. Both qualitative and quantitative data are collected concurrently and analysed separately.

This study used the concurrent triangulation mixed methods design. The design is also concurrently as was recommended by Ivankova et al, 2007. This design is seen as a traditional mixed methods design which researchers use to generate both qualitative and quantitative data, simultaneously, to study a single phenomenon with the aim of comparing the two sets of findings. This was done with a view to determine whether there were similarities, differences or some combination to cope with, well validated findings. In Greene's view, the concurrent triangulation mixed methods design is used when the researcher is attempting to seek convergence or corroboration of results, or and when the researcher uses two different methods of collecting data within a single study. In addition, Creswell (2018) acknowledges that in this design the researcher uses both qualitative and quantitative methods to offset the limitations inherent within one method. Priority in this research design may be given to either the qualitative or the quantitative method. On the other hand, priority is usually equal, and the two sets of results are integrated during the interpretation or discussion phase (Creswell, 2018).

In this study, the researcher used concurrent triangulation design to generate both quantitative and qualitative data concurrently to integrate how STEM strategies were being implemented in teacher education in Zimbabwe. This helped the researcher to confirm, cross – validate and corroborate findings from the study, (Teddle and Tashakkori, 2004). The use of the concurrent triangulation design helped the researcher to collect both quantitative and qualitative data concurrently with the view to offset the weaknesses of one kind of data by the strengths of the other (Harwell, 2001). Furthermore, the use of this design was an advantage to the research as it took less time to complete the data collection and its analysis since quantitative and qualitative were collected concurrently.

Betaha and Cameron (2015) opine that triangulation is among one of the main objectives of mixed methods research. Olsen (2004) defines triangulation as the mixing of data or methods so that diverse viewpoints cast light upon a study problem. Furthermore, Mertens (2003, p. 426) opines that triangulation, 'involves the use of multiple methods and multiple data sources to support the strength of interpretations and conclusions in qualitative research.' In this study, this was done as a way of cross – checking, corroborating and validating the data collected through the questionnaire by means of using face to face interviews, focus group discussions and document review. By using face to face interviews focus group discussions and document reviews, the researcher captured common themes in the perceptions of lecturers, pre – service teacher trainee and ministry officials of strategies used for implementing STEM Education that pre – service teacher trainees were equipped with. Furthermore, triangulation is critical in facilitating interpretive validity (Terre – Blanche 2004, in Maree, 2012). McMillan and Schumacher, 2001, in Maree, 2012) are of the view that triangulation establishes data trustworthiness thus reducing bias. In this study data were collected through the questionnaire and validated using focus group discussion, face to face interviews and document analysis.

Concurrent triangulation design was used to generate qualitative and quantitative data concurrently, to integrate the strategies used for implementing STEM education in teacher education in Zimbabwe. The qualitative data were obtained from focus groups, discussions, face to face, semi structured interviews and document review while quantitative data were obtained from semi structured questionnaires. More so, the integration of findings from the two methods was done during the analysis and interpretation stage of the study. Moreover, this was done with a view to integrate qualitative and quantitative findings side by side in a discussion to provide a comprehensive analysis of the research problem. The questionnaire was presented first to provide an overview of the opinions, trends and attitudes of the participants, followed by the qualitative data and quotations from the transcripts of focus group discussions, interviews and documents reviewed.

3.4 Population

According to Creswell (2018) population refers to a group of individuals that has one or more universal features of concern to the researcher for the purpose of gaining information and drawing conclusions. Yin (2009) defines population as the entire group of individuals or objects which researchers are interested in, in generating their conclusions. Thus, population refers to all members that meet set specifications and from whom the research wishes to gain information. Therefore, these members can also be referred to as the target population. The population of this study included all lecturers from the two teachers' colleges (n=200), all final year pre-service teacher trainees from the general course groups from the two teachers' college (n=504), college management of the two teachers' colleges, University of Zimbabwe Department of Teacher Education Lecturers (n=20) and Ministry of Higher and Tertiary Science and Technology Directors (4).Lecturers were important in this study because they were the ones who equipped pre-service trainees with strategies for teaching. The final year general course students were chosen because they had experienced teaching during their teaching practice. Department of Teacher Education lecturers supervised student teachers and authorized syllabuses for the different teachers' colleges.

Meanwhile, in Zimbabwe there are eleven teacher education colleges that develop primary school teachers. The eleven teachers' colleges are under the scheme of association with the University of Zimbabwe through the Department of Teacher Education (UZ-DTE). Each college designs, develops and implements its own syllabuses in Theory of Education, Professional Development Studies Syllabus A and B and Main Study under the 2-5-2 model (UZ Handbook, 2015). The study focused on the STEM strategies experiences made by final year pre-service teachers and teacher educators, drawn from state owned primary education teachers' colleges. The colleges are identified as College A and B.

Table 3. 3 Distribution of target population

Category	College A	College B	TOTALS
Student Teachers	250	254	504
Teacher Educators	96	104	200
University Lecturers	0	0	20
Ministry Directors	0	0	4

3.5 Sample and Sampling Procedures

Creswell (2018) posits that a sample is a group of elements or a single element from which data are obtained. This study used what Teddlie and Tashakkori (2009) refer to as parallel mixed methods sampling which made use of probability and non-probability sampling strategies concurrently. This was done in consideration of what Elikan, Musa and Akassim (2015, p. 2) say in terms of selecting those from whom data were collected in a study. They observed that,

> *Data gathering in research is crucial because it is meant to contribute to a better understanding of a theoretical framework, it is imperious that selecting the manner of obtaining data from whom the data will be acquired be done since no amount of analysis can make up for improperly collected data*

Ownuegbuzie and Collins (2007) are of the view that sampling is an important step in any research process because it helps to inform the quality of inferences made by the researcher which emanates from the underlying findings. Furthermore, they state that in both qualitative and quantitative studies, researchers must decide the number of participants to select. These form the sample size. Additionally, Owuegbuzoe and Collins (2007) contend that in mixed methods research making decisions about selecting the participants is more complicated because the researchers need to make sample schemes for both the qualitative and quantitative research components of their studies.

In this study the researcher used mixed methods sampling which involves both probability and purposive sampling techniques. The researcher used these sampling techniques because they allowed him to collect complementary sets of data that gave both depth and breadth of information regarding the strategies for implementing STEM Education in Zimbabwe. These techniques also enabled the researcher to acquire both numeric and narrative data to answer the research questions. In collecting quantitative data, the researcher employed random stratified sampling with the aim of generalizing the findings of the study to the population (Owuegbuzie and Collins, 2007). The stratified random sampling included lecturers (Science, Mathematics and Technology = 20), and final year pre-service teacher trainees (n=50) (Science n=16, Mathematics n=18, Information

Communication and Technology 16). Purposive sampling was utilised in the identification of University of Zimbabwe Department of Teacher Education lecturers (n = 3) and Ministry of Higher and Tertiary Education Directors (n = 2). The participants selected enabled the researcher to maximize the information about their experiences and perceptions about the strategies used for implementing STEM Education in Teacher Education in Zimbabwe.

Creswell (2018) opines that, qualitative sampling employs non-probability sampling through techniques such as purposive sampling. Purposive sampling means that the participants are selected with a specific purpose based on the researcher's judgment. Purposive sampling could take the form of criterion sampling in which all participants have to meet some criterion which contribute to quality assurance (Newman, 2006). Neuman (2006) goes on to observe that in purposive sampling the sample is made up of participants who have the most typical or representative attributes of the population based on the researcher's judgment. This study made use of convenience purposive sampling in which the participants were identified because they could contribute meaningfully to the research questions concerning strategies used for implementing STEM education in teacher education in Zimbabwe. In this study, purposive sampling technique was used to identify participants who were accessible and willing to participate. Creswell (2018) notes that, although this technique saves time, money and effort, it could be at the expense of information and credibility.

3.6 Negotiating Entry

The researcher took several measures to get authority to conduct the research as well as gain access to colleges of education for data collection. The researcher obtained an introductory letter from the University of Fort Hare (Appendix B). This confirmed that the researcher wanted to carry out a study on implementing strategies used by teacher education colleges to develop pre-service teachers for STEM education in Harare Metropolitan Province. The researcher applied to the Ministry of Higher and Tertiary Education, Innovation, Science, Technology and Development (Appendix D) for permission to carry out the study in teacher education colleges. This was granted by the

Permanent Secretary in the host ministry. The researcher made appointments for data collection in the identified teacher education colleges. The researcher decided to carry out interviews, focus group discussions as well as document review in each college.

3.7 Data Collection Instruments

The concurrent triangulation design that was used in this study necessitated the simultaneous collection of qualitative and quantitative data (Creswell and Plano Clark, 2007). This provided the researcher with more insights into the strategies used for implementing STEM education in teacher education in Zimbabwe. The data collection instruments included a semi-structured questionnaire, face to face and semi-structured interviews, focus group discussions and document review.

3.7.1 The Questionnaire

Lewis and Throwhill (2007) define a questionnaire as a simple list of pre-set questions structured to elicit data from respondents. There are various types of questionnaires. These include structured, unstructured and semi-structured. In this study a semi-structured questionnaire was used (Appendices M and N) The semi-structured questionnaire was self- administered; it had both open and closed questions. The use of closed questions guided by the 5-point scale helped collation and subsequent data interpretation. The questionnaire had two major categories, section A, focused on soliciting respondent's biographic data. Biographic data was required to determine variables that might influence differences in STEM experiences. Section B focused on STEM implementation; it was further sub-divided in line with the research questions of the study:

(a) Competence of college lecturers to prepare pre-service teachers in STEM Education.
(b) Teaching and learning approaches in STEM Education
(c) Resources, facilities, and support system needed to implement STEM Education
(d) Challenges faced by teacher education colleges when implementing STEM Education
All the questionnaire items were thoroughly selected to ensure their relevance in relationship to the sub-research question.

The questionnaire enabled the researcher to collect large quantities of data over a short period of time (Leard, 2018). It also made it possible for the participants to share information more easily as they enjoyed the freedom to respond to questions (Leard, 2018) due to anonymity. More so, the fact that the researcher administered the questionnaires personally made it cost effective and time effective. The closed-ended questions made it easy for the researcher to analyse data as the responses were quick to code. However, the open-ended questions enabled the researcher to gain insights into the participants' experiences and perceptions on the strategies used for implementing STEM education in teacher education in Zimbabwe.

The researcher personally administered different questionnaires, one for the lecturers, second for one for final year pre-service teacher trainees. The fact that the researcher personally administered the questionnaires to the respondents enabled him to establish a rapport and explain the purpose of the study to the participants (Leard, 2018).

3.7.1.1 Advantages of Questionnaires

The questionnaire assures a high response rate, accuracy of sampling and minimum of bias, providing necessary explanations and giving the benefit of personal contact (Akabayrak, 2000). The use of questionnaires saves money; it is cost effective. Furthermore, questionnaires cover a much larger sample. In this study the researcher self-administered the two giving the chance to explain the purpose of the study and aiding with explanations as participants completed the questionnaires.

3.7.1.2 Disadvantages of Questionnaires

Questionnaires are prone to distortion of data because of the presence of bias. One of the disadvantages of close ended questionnaires is the source of bias (Akabayrak, 2000). The researcher forces participants to choose one or some predetermined alternatives, for example the use of yes or no.

These disadvantages were addressed through the researcher making sure that very few questions used yes or no in the questionnaire. To avoid bias, the researcher left participants completing the questionnaire and collected them the following day.

3.7.2 Face to Face Semi-Structured Interviews

This study used semi-structured interviews. According to Gill, et al (2008), semi-structured interviews consists of several key questions that help the interviewer to determine the areas to be explored and allows the interviewer and/or the interviewee to divulge in detail. Furthermore, Neuwenhuis (2012) agrees with this view stating that the semi-structured interview requires the interviewee to answer a set of answers. Leard (2018) contend that semi-structured interviews are more flexible when compared to structured interviews. To add on, Bryman (2014) opines that using a semi-structured interview, the researcher had a list of questions or specific topics to be covered which could also be referred to as an interview guide. Furthermore, Bryman (2014) states that the interviewee has a lot of leeway on how to respond to the questions. More so, Bryman (2014) posits that questions that are not included in the interview guide may be asked as the interviewer picks up on things said by interviewee. The semi-structured interviews (Appendices) were administered by the researcher to college lecturers from the two teachers' colleges, university lecturers, directors in the MHTEISTD and pre-service teachers from the two teacher's college

The semi-structured interviews helped the researcher in that the interviewees enabled him to explore the strategies used for implementing STEM education in teacher education colleges in Zimbabwe. This was possible as the researcher was able to seek clarity, depth and validity through posing probing questions and asking for further information (Gill et al, 2008). The interviews were audio taped and this made it easy to play back the recording over and over to pick up important issues regarding the main research question.

3.7.2.1 Advantages of Face to Face Structured Interviews

In this study the researcher was able to read non-verbal cues or change in voice inflections of the interviewee, which provided additional insights into issues under discussion (Creswell, 2016). More so, it should be emphasised that interviews provided both the researcher and the interviewee with the opportunity to further elaborate, rephrase and emphasize their points of view.

3.7.2.2 Disadvantages of Face to Face Structured Interviews

Just like any research tool, interview technique has some disadvantages as a data collection tool. Overarching disadvantage is that of collecting biased information due to paraphrasing of questions (Akabayrak, 2000). Furthermore, the technique is time consuming and expensive. The researcher would need more time to conduct the interviews, related to time is the issue of cost.

Meanwhile, a common weakness is that of inaccurate information provided by respondents. As Yin (2009) puts it, respondents are not comfortable giving information to a stranger they have just met for the first time. The researcher had to overcome some of the challenges by rephrasing the questions through pilot study. The issue of cost was managed through collecting data from colleges which were closer to the researcher's workplace.

3.7.3 Focus Group Discussion (FGDS)

A focus group is perceived as a small gathering of individuals who have a common interest or characteristics assembled by a moderator who uses the group and its interactions as a way to gain in-depth information about a particular topic (Leard, 2018). Marizak and Sewell (2007) view focus group as a group interacting individuals having some common interest or characteristics brought together by a moderator who uses the group to gain information on a specific or focused issue. Furthermore, focus group discussions are group interviews which generally range from 6 to 12 participants who are familiar with one another and have been selected by a researcher (Anderson, 1993). Therefore, it implies that a focus group must be made up of people who are from the same background and who share common ground on the topic or subject understudy. In this study focus group discussions were made up of 5 participants. This study conducted focus group discussion with pre-service teacher trainees eliciting their views and experience of the strategies used for implementing STEM Education in Teacher Education in Zimbabwe. The focus group discussions enabled the researcher to understand the strategies used for implementing STEM education in teacher education from the participants' point of view (Khan and Manderson, 1992 in Dilshord and Lahf, 2013). The focus group discussions were an eye opener for the researcher and helped him acquire rich data which enhanced the interactions among the participants as they provide checks and balances on each other (Casey and Kruger in Patton, 2000). The group members had the opportunity to provide immediate feedback and clarification on other members' contributions and this further added to the rich data collected by the researcher (Goman and Clayton, 2005).

The researcher personally conducted the focus group discussions and was the moderator in each of the discussions made up of 5 members. This was an advantage to the researcher, as it enabled him to take notes of both the spoken words and extra linguistics features such as gestures and facial expressions. The focus groups were conducted in the college boardrooms for final year pre-service teacher trainee. This enabled the participants to express themselves freely without bias since the atmosphere was more relaxed (Marshall and Rossman, 2011) and the environment was more natural as the members of the group felt at home.

The researcher was the moderator; he started off the discussion by introducing himself then allowed the members in each group to do the same. This created a relaxed atmosphere for rapport between them and the researcher.

Additionally, the researcher explained the purpose of the research and why the focus discussion was being conducted before seeking informed consent from the participants. All the discussions were audio-taped for later transcription and gestures and facial expressions were recorded in a notebook for further considerations.

3.7.3.1 Advantages of Focus Group Discussions

The use of focus group ensured that the study would produce valuable research data in the shortest possible time. Meanwhile, Robson (2002) opines that focus groups have the following merits: they generate data quickly, develop themes, topics and schedules that may be used in subsequent research interviews on a topic or use of questionnaires appropriate for the generation of data on attitudes, values and opinions of different sub groups of a population and encourage groups to voice their own opinions on an issue. As such, focus groups are cost effective and can provide more depth and variety as compared to face to face interviews.

3.7.3.2 Disadvantages of Focus Group Discussions

Meanwhile, focus groups are dynamic (Maree, 2007). They are time consuming if not administered properly (DeVos et al 2011). It should also be noted that some participants would dominate discussions (Maree, 2007). To mitigate these challenges, the researcher had to first establish ground rules with the participants.

3.7.4 Document Review

In document review as a data gathering instrument, the researcher focused on all types of written communication that may shed light on the phenomenon that the researcher was investigating (Maree, 2007). Furthermore, Nieuwenhuis (2012) states that documents may include published and unpublished material such as company reports, memoranda, agenda, administrative documents, letters, reports, email messages, faxes, newspaper articles, etc. these are primary and secondary sources of written documents. More so, Nieuwenhus (2012) posits that primary sources, are generally data that is not published which the researcher gathers from the participants, directly, for example, minutes of meeting, reports, lecture programmes and lecture notes.

In this study the researcher reviewed documents which had a bearing on the strategies that were being used for implementing STEM Education in Teacher Education in Zimbabwe. The researcher reviewed documents such as lecture’s lecturing programmes, syllabuses for main study and professional studies syllabus B (PSB) of the STEM subjects being offered in the teacher training colleges. The documents were reviewed with the aim of determining the strategies that pre-service teacher trainees were equipped with by their lecturers to effectively teach STEM subjects.

3.7.4.1 Advantages of Document Review

Document review is an efficient method as it is less time consuming and therefore more efficient than other research tools (Bowen, 2017). Also, document review is cost effective than other research tools. Furthermore, there is lack of obtrusiveness and reactivity (Bowen, 2017) that is, they are unaffected by the research process. It counters the concerns related to reflexivity inherent in other research tools. Reflexivity in an awareness of the researcher's contribution to the construction of meanings attached to social interaction and acknowledgement of the possibility of the investigators influence on the research (Bowen, 2017). More so, documents provide broad coverage, they cover a long span of time, many events and many settings (Bowen, 2017). Meanwhile, many documents are in the public domain, with the advent of the internet and attainable without the owner's permission it makes document review and attractive option for research (Bowen, 2017).

3.7.4.2 Disadvantages of Document Review

There is insufficient detail in documents as they are developed for some purpose other than research; they are created independent of the research agenda (Bowen, 2017). More so, documents have low retrieval rates as Bowen (2017) has noted that access to documents may be deliberately blocked.

Given its efficiency and cost effectiveness in particular, document review offers advantages that clearly outweigh the limitations. In this study, document review served its purpose of triangulation and the researcher explained its purpose and it was made accessible by the responsible authorities.

3.8 Validity and Reliability/Credibility/Trustworthiness

In quantitative research as far as the research instruments are concerned, validity and reliability are crucial aspects while in qualitative research these aspects are looked at in terms of credibility and trustworthiness (Niuwenhuis, (2012 and Kusi, 2017).

3.8.1 Validity and Reliability

Kusi (2017) says validity refers to correctness, relevance and strength of collected information in relation to the purpose of the research. In addition, Bryman (2014, p.171) says validity refers to the issues of whether an indicator (or set of indicators) that is devised to gauge a concept really measures that concept.

This study ensured validity through matching each questionnaire item with research questions from which it was generated, for example, what teaching and learning approaches are used to prepare primary STEM pre-service teachers?(sub-research question) Rate the teaching and learning methods used to prepare primary STEM pre-service teachers.(questionnaire item) Generally, each item was a solution to the research questions. Validity was also enhanced through careful sampling, appropriateness of instruments and level of data analysis (Mertens, 2010).

In this study the questionnaire for gathering qualitative data was pre-tested with a smaller sample and a pilot study was done after which items that appeared unclear were revisited to be able to get the responses that addressed the research questions focusing on the strategies used for implementing STEM Education in Teacher Education in Zimbabwe.

According to Kusi (2017) research reliability is mainly concerned with whether the instruments are really measuring the phenomenon they are supposed to measure. Furthermore, Bryman (2014, p.19) says reliability refers to the consistency of a measure of a concept. Therefore, reliability of a research instrument could be summarized as referring to the extent to which the instrument is consistent. In this study reliability was acquired through pre-test and retesting the questionnaire on a selected section of the population.

3.8.2 Pilot Study

To ensure validity and reliability, a pilot study was undertaken. For this study, a pilot study was undertaken to afford the researcher the opportunity to rephrase the questionnaire items and interview questions and other research instruments (Clark and Creswell, 2014). Pilot study ensure that the researcher correlated the questions or checklist with what the study intended to measure (Baines, 2010, Cohen, Mannion and Morrison 2007). A pilot study was carried out; a retest was done with eight lecturers and ten final year students outside the two colleges of education in Harare were conveniently sampled, Johnson and Christensen (2012) advised that the thumb rule in any research instruments particularly the questionnaire, must be tried out with five to ten prospective research informants. This was done to afford the respondents the chance to identify errors so that measures were taken to reduce them before data collection. Pilot study was done after getting permission from the Ministry of Higher Education and with the supervisor's authorization that the instruments were ready for fieldwork. The researcher made several visits to the identified institutions by prior arrangement with the college management. The lecturers and student teachers were asked for additional questions or aspects to enrich the instruments. The participating respondents were asked to give their overall evaluation of the research instruments and provisions thereof. After making the required amendments on the research instruments particularly the questionnaire on professional development, the main investigation was carried out.

3.8.3 Trustworthiness

According to Creswell (2018) trustworthiness is about making sure that research findings are accurate and detailed as seen from the standpoint of the researcher himself/herself, the participants and the readers. The following aspects make up the trustworthiness of qualitative research: credibility, transferability, dependability and conformability.

3.8.4 Credibility

Bryman (2014) states that credibility means that the researcher ensures that the research is carried out according to the principles of good practice. The researcher ensured credibility by making sure that the sample was representative enough, that is, neither too small nor too large. The researcher made sure that the sample was 10% of the total population of the study. The study ensured credibility through accurate description of the research informants (teacher educators, university lecturers, student teachers and directors), research procedures and research instruments in case undertakes the research using similar techniques (Leed and Ormrod, 2005). Furthermore, research instruments were constantly checked to ensure that instructions were not ambiguous. The researcher made sure that he harbored his opinions on issues under probe during the interview sessions. Further the researcher factored in suggestions from the supervisor, colleagues and other research participants on research instruments or the entire research process. Also, the researcher utilised member checking. The researcher made use of teacher educators who were not part of the research sample, to examine the interpretations made. Several the participants were asked to review the researcher's interpretations. The researcher maintained a balanced perspective when collecting, analyzing and interpreting quantitative and qualitative data. The study made effort to accurately report research findings, verbatim accounts and remarks from participants.

To ensure that research findings were authentic the study used triangulation of instruments – interviews, focus group discussions, document review and questionnaires.

3.8.5 Transferability

Transferability is the extent to which the results of qualitative research can be transferred to other settings or contexts (Kusi 2017). To obtain transferability in this study, the researcher presented findings in the form of thick descriptions and report findings verbatim. In this study transferability was done through providing detailed descriptions of the entire research process, interrogation of strategies used for STEM implementation, themes and through consultation of requisite literature.

3.8.6 Dependability

The third quality assurance aspect that was considered in this study was dependability of the research findings. The concept of dependability is concerned with whether the study would obtain the same results if it were to be repeated by another researcher (Babbie, 2010). This study accomplished dependability through use of various data collection instruments and using academic peers as auditors of all processes. Furthermore, dependability was achieved by describing in detail the research sample, data collection, analysis, subsequent judgment and overall report writing procedures (Cohen, Mannion and Morrison, 2007).

3.8.7 Conformability

Bryman (2014, p. 392) posits that conformability is concerned with ensuring that while recognizing that complete objectively is impossible in social research, the researcher can be shown to have acted in good faith. This study made sure that recording and findings were presented verbatim, thereby producing the rich accounts of them. The researcher documented all the procedures, checking and rechecking the data throughout the study. The researcher received critical feedback from the supervisor and colleagues that was used to reshape the whole process which included report writing.

3.9.0 Data Collection Procedures

Having received approval from the MHTEISDT. The researcher visited each college researcher decided to personally deliver the questionnaire to the teacher educators and pre-service teachers where he made the necessary explanations. The dates for collection were arranged. On the day of collection some teacher educators and pre-service teachers had forgotten to complete the questionnaire. The researcher had to arrange for another day to collect the questionnaire

3.9.1 Interviews

The researcher met with teacher educators at their respective colleges and workplaces and explained the study and interview guide and process that would unfold during interviews. The permission letter for the interview was made available. The teacher educators and pre-service asked for some clarity on certain matters to do with anonymity, interview dates and time, and their inputs were taken on board. During interviews, verbal interactions were recorded for later transcriptions. Notes were taken on aspects to be followed-up or unclear statements or important points (Merriam &Tisdell,2016). The average time for the interviews with teacher educators, university lecturers and directors were 40 minutes. On several occasions, the researcher had to pose probing questions that were completely different from those planned. The idea was to get much data on their views as possible.

3.9.2 Focus Group Discussion

On arrival at the two colleges on the agreed dates, the researcher explained the applicable ground rules before commencing. The researcher was concerned with the quality of the recording so he explained that participants should wait for their chances to speak.

3.9.3 Document Review

The researcher established at the start of the review from participants that documents would be available and accessible following documents were reviewed, teaching programmes STEM syllabi, external assessment reports and lecture notes.

3.10 Data Analysis

Chen et al (2011) stresses that data analysis involves organizing raw data into a system that reveals the basic results from the research. They are arranged, ordered and presented in some reasonable format that permits decision makers to quickly detect patterns in the data. In mixed methods research data analysis relates to the types of research design chosen for data collection (Creswell and Plano Clark, 2007). This study used concurrent triangulation mixed methods research. This involved conducting a separate initial data analysis of both qualitative and quantitative data comparing the findings from both sets of data during the discussion and interpretation stage.

3.10.1 Qualitative Data analysis

The researcher recorded the interviews and focus group discussions to capture them accurately as given by participants. Recorded audio tapes were played several times during transcriptions. Parsons (1997) maintains that it is necessary to play and replay the recorded information for accuracy of information from which to prompt for more questions for subsequent interviews. Interviews were transcribed word for word, then organized according to specific themes and analysed in response to specific research questions. The researcher transcribed data soon after the interviews

3.10.1.1 Unitising, categorizing and the formation of themes

During data processing various concepts were used, these included data unitizing, categorising, patterning and forming data themes as explained below.

3.10.1.2 Coding and unitizing

Coding allows the researcher to identify and organize the data into important patters or themes, hence coding of the collected data is the first step in qualitative data analysis (Mertens,2006) The researcher used key research questions of the study as the stems and sub-research questions as sub stems. The coded and unitised data were organized into categories.

3.10.1.3 Categorisation of units

Categories were the research question to be answered, and therefore responses from interviews were reviewed and words or phrases were allocated to a relevant category. The researcher used research questions as guiding categories to ensure that all set questions were answered from the gathered data, sometimes participants views were similar which resulted in the formation of one category, and when responses to similar questions produced varying points of view multiple categories were identified. Themes were identified from the categories which were then discussed relating to the literature reviewed.

3.10.1.4 Themes

Bryman (2012} defined a theme as a category identified by data analysts during the process of unitizing and categorizing the data. A theme builds on codes identified in transcripts, after unitizing and categorization. Themes may include knowledge, beliefs, experiences or opinions that participants were trying to communicate (Parker2007). Bryman (2012) recommended that one should look out for,

-Repetitions: that is, topics that recur.

-Indigenous typologies or categories- local expressions that are ither unfamiliar or used in an unfamiliar way

-Transitions: the way in which topics shift in transcriptions and other materials.

-Similarities and differences: exploring how interviews might discuss a topic in different ways or differ from each other in certain ways.

3.10.2 Quantitative Data analysis

Quantitative data were analysed statistically to help answer the study's research questions (Creswell, 2003). The main purpose of statistical analysis was description and inference (DeVaus, 2001). The questionnaires collected were analysed using software called Statistical Product and Service Solutions (SPSS). Once data were captured and coded into SPSS, descriptive statistics were used in the form of frequency tables, graphs and pie charts.

3.11 Ethical Consideration

According to Iseral and Hay (2006) in Creswell (2018), researchers need to protect their research participants, develop a trust with them, promote the integrity of research, guard against misconduct and impropriety. Furthermore, Creswell (2018) suggests that any researcher needs to consider codes of ethics and obtain necessary permissions before carrying out a research study. As such, this study was guided by the University of Fort Hare Research Ethics Policy of 2011 and the Post Graduate Qualification Policies and Procedures. These were ethical issues to be considered which include the following, as suggested by Diener and Grandell (1978) in Bryman (2014, p.135).

i. Whether there was harm to the participants,
ii. Whether there was lack of informal consent,
iii. Whether there was invasion of privacy, and
iv. Whether deception was involved.

3.11.1 Anonymity and Confidentiality

Meke (2011) opines that in research, the right to confidentiality and the right to anonymity put the participants at ease to give information which might otherwise be regarded as sensitive. It is, therefore, important that participants be assured of the researcher's adherence to issues of confidentiality. According to Kusi (2017) confidentiality is the ability to protect the privacy of participants by keeping the data sources as confidential and private as possible, while anonymity refers to discussing the identity of the participants. Instead of using real names of the participants fictitious or pseudonyms are used. In this study, the researcher ensured that the individuals remained anonymous using pseudonyms. Information may be quoted and used, but the identity of the individual remained highly protected.

3.11.2 Informed Consent

Diener and Crandall, in Cohen et al (2000) view informed consent as the procedure in which individuals choose to participate in an investigation after being informed of the purpose of research. Kusi (2017) acknowledges that there is need to obtain the consent and cooperation of subject who are to participate in the investigation. In this study, the researcher got permission from the responsible authorities, that is, the Ministry of Higher and Tertiary Education Science and Technology Development to access the research sites. The principals of the two colleges too had to be approached and agreed to the study timelines, in line with the colleges' curriculum. After getting permission the researcher made appointments with the sampled participants for the interviews and the respective Heads of Departments (HODs).

3.11.3 Voluntary

The researcher furnished the participants with full information on the aims and objectives of the study, their involvement, methods and procedures that were to be followed. All the participants of the individual and focus group interviews were provided with informed consent forms that clearly stated the purpose of the study, that their participation was voluntary, that they could discontinue the participation at will, and their responses were to be held in the strictest confidence they deserved. The researcher respected the participants' right to know that their involvement was voluntary all the time and that they had the right to refuse to take part or to withdraw once the research had begun, hence informal consent implies informal refusal (Creswell, 2018).

3.12 Summary

This chapter discussed the research methodology used in the study. Justification and execution were made on the adopted research paradigm, research approach, research design, population, sample and data collection, sampling procedures, instruments and data analysis procedures, Issues to do with reliability, trustworthiness, validity and ethical consideration were examined and explained. The next chapter looks at detailed data presentation and analysis.

CHAPTER 4
DATA PRESENTATION AND ANALYSIS

4.0. Introduction

This chapter presents and analyses the results and findings of the study. The study aimed to interrogate implementing strategies used by teachers' colleges to prepare pre-service teachers on Science, Technology, Engineering and Mathematics (STEM) in Zimbabwe. The data from the questionnaires guided the presentation while data from interviews, focus groups and document review augmented that from the questionnaires. This was done in the spirit of triangulating. The researcher gathered data through qualitative and quantitative methods in line with mixed methods research approach. Quantitative data were mainly solicited through questionnaires and were self-administered by the researcher to 20 teacher educators and 50 final year student teachers from two teacher education colleges, here identified as College A (CA), and college B (CB). Statistical data representations were made through graphical representations such as the use of frequency tables, pie charts, bar graphs and line graphs. The descriptive statistics were used to clarify and give summation of the main points. On the other hand, qualitative data were solicited from respondents using the following instruments: semi-structured interviews, focus group discussions and document review. Qualitative responses were verbatim quotations made to accurately capture the expressions of the respondents. Ten lecturers and twenty student teachers from each college participated in the interviews and focus group discussions. Furthermore, documents such as course outlines, STEM syllabus, teaching programmes and examination papers were reviewed to check on the methodologies and content adequacy of different STEM disciplines.

4.1 Code Identification

For identification purposes, the researcher coded all research cases or respondents, interviewees and those who completed the research questionnaires. The codes used are given below.

- CAL - College A Lecturer
- CBL - College B Lecturer

- CAST - College A Student Teacher
- CBST - College B Student Teacher
- CALFGD - College A Lecturer Focus Group Discussion
- CBLFGD - College B Lecturer Focus Group Discussion
- CASTFGD - College A Student Teacher Focus Group Discussion
- CBSTFGD - College B Student Teacher Focus Group Discussion
- CALI - College A Lecturer Interviewee
- CBLI - College B Lecturer Interviewee
- CASTI - College A Student Teacher Interviewee
- CBSTI - College B Student Teacher Interviewee
- UL1I - University Lecturer 1 Interviewee
- UL2I - University Lecturer 2 Interviewee
- DHO1I - Director Head Office 1 Interviewee
- DHO2I - Director Head Office 2 Interviewee

For this study, both questionnaire respondents and interviewees used pseudonyms. Questionnaire respondents were further allocated number to easily capture data on SPSS package. For example, lecturers were coded in the format CALI; meaning College A Lecturer Interviewee, in the same way CBST meant College B student teacher. In this study the pseudonyms were used and identification codes such as CALHSM.

The respondents in the study were lecturers from two primary teachers' training colleges in Zimbabwe, lecturers from the Department of Teacher Education, University of Zimbabwe, directors from the Ministry of Higher and Tertiary Education, Science and Technology Development and pre-service teacher trainees from the two teachers' colleges. Lecturers from the two colleges were purposively identified using letters of the alphabet. The data were presented in four main themes developed from sub-research questions. Theme one (1) focused on the competence and skills of college lecturers. Theme two (2) focused on delivery methodology used by pre-service trainees. Theme three (3) focused on resources, facilities and support available in teachers' colleges and theme four focused on why teachers' colleges were facing challenges in implementing STEM in Zimbabwe.

4.2 Biographic Information for Lecturers

This section of the questionnaire sought to establish biographic information for the lecturers in terms of their preferred pseudonym, gender, age, lecturing experience, qualifications, job title and the department in which they were operating. This was meant to ensure that different perspectives across gender, age, experience and different STEM subject areas were presented.

Table 4. 1 Biographic Variables for Lecturers (n=20)

Biographic Variable	Variable Description	Frequency	Percentage
Gender	Male	19	95
	Female	1	5
Age	31-40	1	5
	41-50	12	60
	51-60	7	35
	Over 60	0	0
Teaching experience in Teacher Education	1-5	2	10
	6-10	8	40
	11-15	8	40
	16-20	2	10
Highest professional qualification	PhD	0	0
	M.Ed.	9	45
	B.Ed.	10	50

	DipEd	1	5
Job titles	Lecturer	3	15
	Senior Lecturer	5	25
	Principal Lecturer	6	30
	LIC/HOD	6	30
STEM Subject specialization	Mathematics	8	40
	Computer science	6	30
	Biology	2	10
	Chemistry	2	10
	Physics	2	10
	Engineering	0	0

The biographical variables for teacher educators (Table 5) indicated that respondents to the questionnaires were drawn from a wide spectrum of STEM backgrounds. As indicated on Table 5, most of the respondents, (n=19) were males while 5 (n=1) were female. For this study, there were more males than females. This could be explained by the nature of subjects under study. STEM subjects are mainly studied by males and few females undertake such subjects. This could be attributed to gender influence on what to study at high school as determined by societal values. Most of the respondents 95% (n=19) were above the age of 41. While 5% were above 50. This indicated that most of the lectures were very mature in terms of age, something that could have influenced the way lecturers handled and prepared pre-service student teachers. Qualifications and experience have influence on people's attitudes, perceptions, beliefs and values in terms of STEM Education and its implementation. Teacher educators with at least a master's degree were 45% (n=9). However, most of the teacher educators had a bachelor's degree, 50% (n=10). Thus, for this study, most of the STEM teacher educators had a bachelor's degree. It should be noted that the level of education has an impact on one's self efficacy.

In terms of teacher educators' professional standing, it should be noted that 85% (n=17) of them were in the senior lecturer grade and above. Therefore, most of them were seasoned teacher educators. In addition, the respondents were specialist in STEM subjects, Mathematics 40% (n=8), Computer Science 30% (n=6), Biology 10% (n=2), Chemistry 10% (n=2) and Physics 10% (n=2) respectively, as shown by the Figure 12.

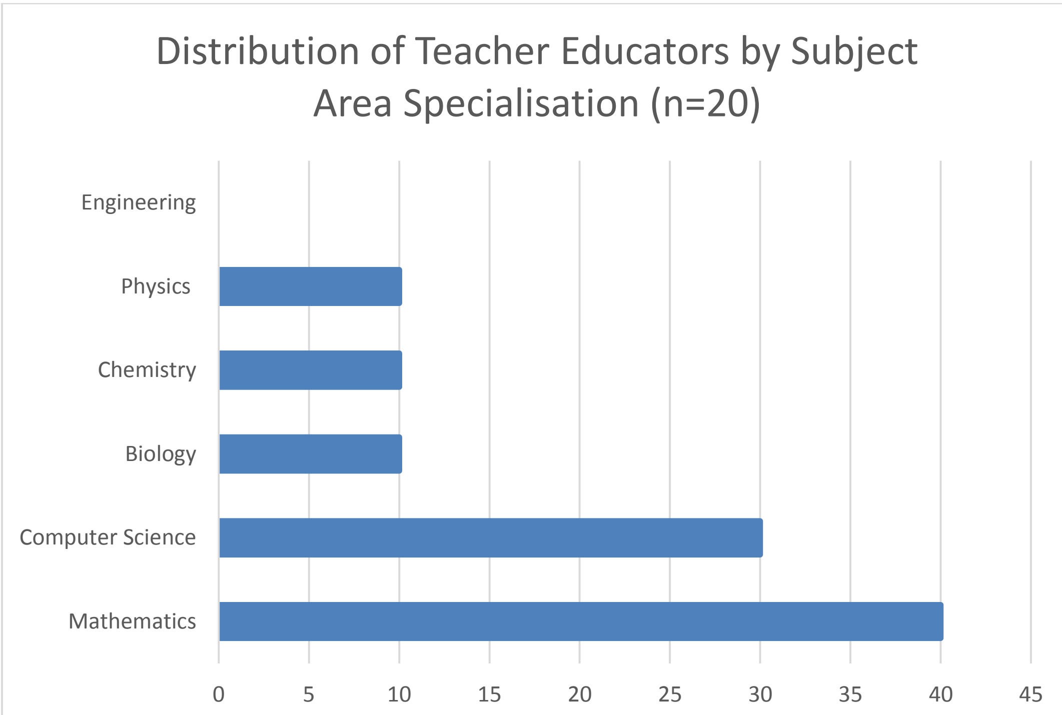

Figure 4. 1 Percentage Distribution of Teacher Educators by Subject Area Specialisation (n=20)

From the data collected through questionnaires, it was evident that teacher educators were quite mature with relevant professional experience to provide diversified views regarding the implementation of STEM in Zimbabwean teacher education colleges. The respondent's' background gives hope to the researcher of diverse and complementary views regarding the strategies for STEM implementation in Zimbabwe. Having addressed biographical variables for teacher educators, the next focus was on biographical variables for student teachers who were part of this study. Table 6 indicates the biographical variables of student teachers.

Table 4. 2 Biographical Variables for Student Teachers (n=50)

Biographical Variable	Variable Description	Frequency	Percentage
Gender	Male	10	20
	Female	40	80
Age	20-25	3	6
	26-30	21	42
	31-35	15	30
	36-40	8	16
	Over 40	3	6
Highest academic qualification	O- Level	40	80
	A-Level	10	20
STEM Area of Specialization	Mathematics	10	20
	Computer Science	12	24
	Chemistry	13	26
	Biology	7	14
	Physics	8	16
	Engineering	0	0

It was quite evident from the biographical data for student teachers (Table 6) that responded to the questionnaire, were drawn from different STEM backgrounds. Most of the respondents 80% (n=40) were female, while 20% (n=10) were male. Most of the respondents 50% were above the age of 30. It was also noted that 40% of the student teachers had Ordinary Level as their highest academic qualification, whereas 10% had Advanced Level. This meant that the respondents had an interface with Science and Mathematics at some point in their educational career. Also, it was government policy that every student enrolled in a teacher education college should have passed 5 Ordinary Level subjects, including English Language, Science and Mathematics. Therefore, the respondents were not blank slates in terms of STEM Education. This background was of significance when it came to discussing and interrogating STEM related issues. Additionally, 100% of the respondents were specializing in STEM subjects. This showed that teacher education candidates were gradually becoming specialists in some of the STEM subjects at primary level. However, it should be noted that those student teachers who had A -Level, selected teaching because they had failed to secure places at different universities around the globe. Therefore, teaching was their last resort. On the other hand, it was also sad to note that Engineering was not on offer in these two teacher education colleges. This development had a bearing on how STEM was implemented in teacher education colleges and ultimately in primary schools in Zimbabwe.

4.3 Available STEM Policy

The study saw it fit to consider issues that had to do with policy. Government policies guided and set parameters for STEM Education implementation. The respondents were asked to estimate according to their experiences, the availability of STEM Education policy in Zimbabwe. The respondents were teacher educators and directors.

The results from the respondents indicated that the teacher educators were aware of the existence of STEM policy in the country and scores were higher on those who were sure compared to those who were not sure. The mean difference is statistically significant, with a $t = 3.356 > 2$ and p – value $= 0.001 < 0.05$. this shows that those with STEM policy knowledge have higher scores. It was evident in a way they implemented STEM education in their colleges. The following were narratives presented by the respondents:

CALHSM commented,

I have read about Zimbabwe Science, Technology and Innovation (STI) cited in several policy documents. The part that was of interest to me as a Mathematics lecturer was that Mathematics was made compulsory at all levels. Learners were to study Mathematics at primary and secondary level. This policy is good for the country, especially, if STEM Education STEM Education is to be successful.

CBL Duncan acknowledged,

I have heard that there is a policy which compels every O -Level secondary students to study Mathematics and two other Science subjects. So, to be deemed pass at O-Level one should have 5 O-Levels including Mathematics, 2 Science subjects and any two others. This is enshrined in the policy document.

CAL Takawira commented,

I have seen a policy document on STEM Education. The STEM document acknowledges that Zimbabwe is gradually moving towards STEM Education. The students are going to study Science, Technology, Engineering and Mathematics.

CAL Mashavave opined,

I have read the Science, Technology and innovation document of 2012 which outlines how the government of Zimbabwe would want to stimulate economic growth through STEM Education. The document clearly outlines the goals for STEM Education STEM Education in the country.

CBL Machona commented,

There is a STEM policy in Zimbabwe. The policy is well crafted to ensure clarity. This STEM policy had made Science and Mathematics compulsory at O- Level. At college, the entry qualifications are 5 O- Level including Mathematics, Science and English. This policy is the guiding framework for recruitment of preservice teachers in teacher education colleges.

DHOI 1 acknowledged,

In Zimbabwe we now have a STEM policy that spell out how STEM was going to be implemented. The policy document has 6 main goals that are well spelt out for guidance. The blueprint is available in all colleges for assistance.

DHOI 2 indicated:

We have established the Ministry of Science and Technology Development and launched the second Science, Technology and Innovation policy in 2012. This was meant to make new technology an integral part of individual and national development. This is meant to divide universities and colleges in terms of technology and policy issued.

4.4 Policy Inconsistency and Imposition

The study saw it fit to consider issues that have to do with policy. Government policies guided and set parameters for STEM implementation. Respondents agreed that there were policy inconsistencies and imposition by the government on teacher education colleges from the following narratives:

CBL Takawira acknowledged,

In Zimbabwe there are many policies that were crafted. The MOHTEIST has several term related policies. MOPES has several STEM related policies as a result these two ministries develop parallel policies. As such there are a lot of policy inconsistences in the country. This affects the operations of teachers 'colleges in Zimbabwe.

CBL Mahingi had this to say:

If there are two ministries of education developing policies in their respective ministries, then there is a problem in the country. This is going to affect how the *policies are going to be operationalized. It may lead to inconsistences and conflict of policies.*

CALI Nyamuscom commented:

I have heard that there is a STEM policy. The problem in this country is that policies follow a top -down approach. There is no stake holder consultation. A lot of policies were crafted without consultation. Such policies lack ownership and acceptance by different stakeholders. The Government needs to consult like what happens in other countries.

CBL Duncan opined:

STEM policy is amongst us, but we are not sure how it was crafted and how it would be implemented in colleges. The government should make sure that whenever they want to introduce a policy, they should consult different stakeholders. The stakeholders should also give their own input to such critical issues that affect the nation.

CBLI Kudakwasherombe explained:

In Zimbabwe there are two ministries of education, MOEPS developed STEM policy specifically for the consumption of that ministry. On the other hand, the Ministry of Higher and Tertiary Education, Innovation, Science and Technology Development implemented its own policies. As such there is inconsistence and conflict between these two ministries' policies.

CBL Machona commented:

The problem in Zimbabwe is that policies are never negotiated. The STEM policy was never negotiated. It was imposed on colleges. The colleges were asked to implement the STEM policy. At the end of the day such policies face resistance from stakeholders.

CBL Mahingi, had this to say:

These are policy inconsistencies and imposition in Zimbabwe. The two Ministries of Education should be corroborating with other stakeholders in policy formulation. However, each ministry seems to develop its own policies and as such the policies end up seemingly contradicting. More so, these policies are not negotiated, they are imposed upon stakeholders.

ULI2 echoed:

The current policy is an imposition and lacked prior consultation of those who were going to implement it.

Having presented the participants' biographic data, the focus is now given to participant's responses pertaining to sub-research questions based on implementing strategies used by teacher education colleges to develop pre-service teachers for STEM Education.

4.5 Knowledge of STEM Education by Teacher Educators in Primary Education Colleges

Knowledge of STEM Education formed one of the integral parts of this research. Knowledge of STEM was considered a key enabler in the implementation of STEM Education in teacher education colleges. Knowledge of STEM was critical in understanding content knowledge, pedagogical content knowledge and technological pedagogical content knowledge as all these encompass the competence and skills of the teacher educators. Knowledge of STEM would influence the way the teacher educators would teach and select methods of implementing STEM. This section was to establish and take a close look on how STEM was understood by different respondents in the context of their experience in teacher education colleges in Harare province. This section was concerned with competence and skills of teacher educators in teaching student teachers. Also issues to do with the philosophy or the utility of STEM formed part of the section.

4.5.1 Understanding STEM Education

All the respondents for this study were asked this question. What is STEM? Responses were obtained from the following categories, teacher educators, student teachers and university lecturers.

4.5.1.1 Teacher Educator's Understanding of STEM Education

The teacher educators' responses were categorized into two distinct parts generated from how they defined STEM Education. Figure 4.2 shows two response categories together with teacher educators aligned definitions.

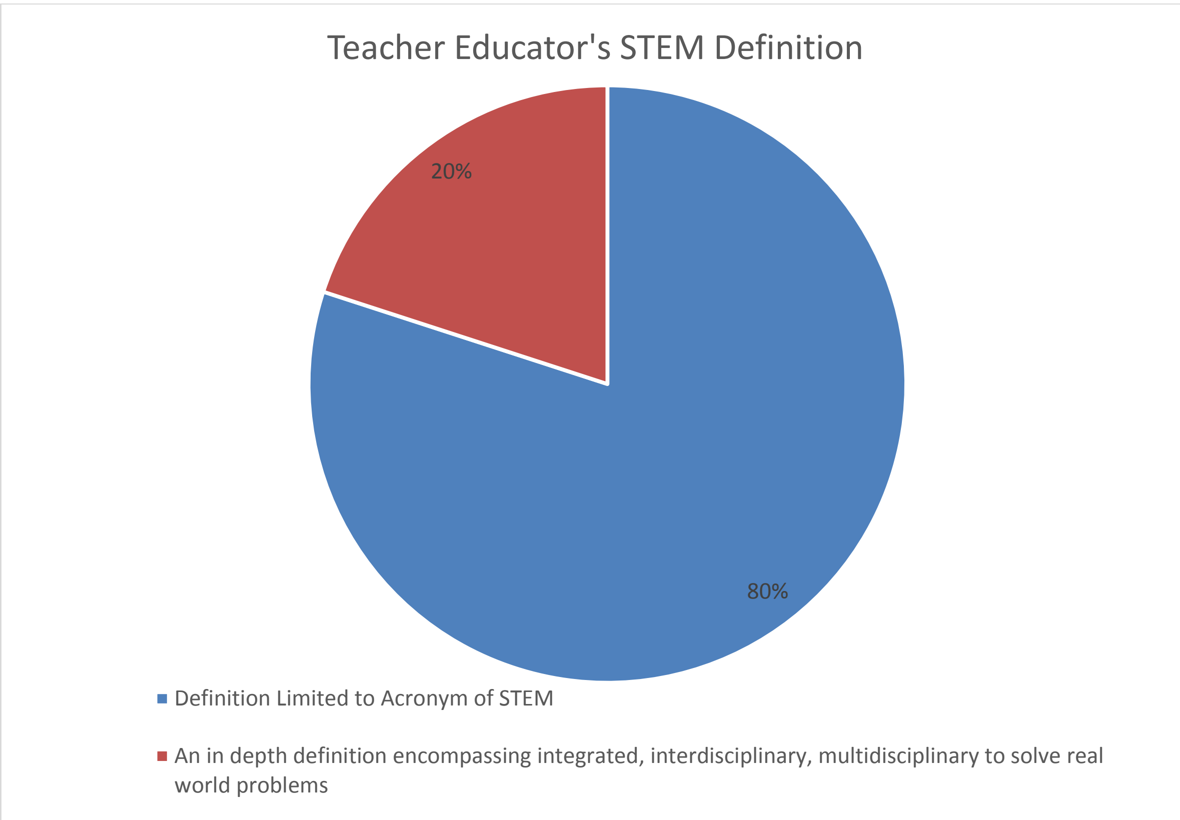

Figure 4. 2 Teacher Educator's understanding of STEM Education

Most teacher educators 80% defined STEM Education as the education or learning of Science, Technology, Engineering and Mathematics to develop in terms of research and science. While 20% defined it as a pedagogical approach in which concepts and objectives from two or more STEM disciplines are incorporated into a single project so that students are exposed to the connections among and across these concepts and or practices, learn or apply the concepts simultaneously rather than in isolation and relate them to real life situations. According to the data gathered, there was evidence to suggest that some lecturers had limited perception or knowledge about STEM as their definitions were limited to the acronym STEM. However, other lecturers had a broader and deeper understanding of STEM as noted below.

4.5.1.2 University Lecturer's' Knowledge of STEM Education

According to university lecturers, STEM Education was viewed as an integrated interdisciplinary, fused, trans-disciplinary and thematic teaching. These perceptions were presented as follows.

UL2: Provided a detailed and comprehensive meaning of STEM in relation to the university lecturer's' perceptions. He concurred:

> *I see STEM as formulated on the idea of instructing students in four specific subjects, Science, Technology, Engineering and Mathematics in an interdisciplinary approach. For instance, instead of approaching a topic as a separate entity, STEM attempts to integrate all four into single mode based on real life applications. STEM Education emphasises incorporating all four disciplines together to allow students to develop real world skills.*

UL1: Decided to broaden the definition by incorporating the importance of STEM to the economy, in general and industry. He opined:

> *It is the acquisition of scientific knowledge and application of scientific knowledge and education in an innovative setup and design and use of relevant scientific programmes and structures that formulate problem solving in industry.*

UL3: Concurred

> *STEM Education is in line with current industrial needs of our country. It is that education which is important in equipping nations with the necessary skills to move forward and improve people's standard of living in general. It is that education which equips learners with knowledgeable skills and values*

that guarantee economic growth and the process ensuring prosperity of the nation.

In the stated quotes of STEM Education, there seems to be differences or variations on what STEM is or embraces. However, the emerging issues were that STEM Education is multifaceted and whatever angle it is perceived from, it impacts on the learner's skills and knowledge and that it is integrated and multidisciplinary in nature.

4.5.1.3 Pre-service Teacher's understanding of STEM Education

As a result of diversified backgrounds in terms of STEM subject specializations, the definitions could again be categorized into two distinct classes, one limited to the definition of acronym and another one encompassing and comprehensive. The pre-service teachers whose understanding of STEM was limited to the acronym had the following perceptions.

CAST: Opined

It is the teaching and learning of Science subjects such as Science, Technology, Engineering and Mathematics education.

CBST: concurred

It is curriculum based on the idea of educating students in four specific disciplines that is, Science, Technology, Engineering and Mathematics.

CAST acknowledged:

It is Science, Technology, Engineering and Mathematics.

CAST concurred,

STEM is an acronym which stands for Science, Technology, Engineering and Mathematics.

On the other end of the continuum, 80% pre-service student teachers had a deeper, comprehensive and more encompassing understanding of STEM Education just like in the case of their lecturers. They had the following perceptions.

CAST12 defined it as:

> *It is an interdisciplinary approach to learning, whereby rigorous academic concepts are involved with real world lessons, as learners apply: Science, Technology, Engineering and Mathematics in real world concepts.*

In the same vein, CABST9 echoed:

> *It is an approach whereby academic concepts are involved with the real world as learners apply Science, Technology, Engineering and Mathematics.*

In the aforesaid STEM definitions, there are considerable convergences. Defining STEM as Education of Science, Technology, Engineering and Mathematics was the common trend among the college lecturers, university lecturers and pre-service student teachers whose definition was limited to knowledge of the acronym. However, there were subtle differences among the same groups in terms of depth in understanding STEM Education. These differences could be because of diversified backgrounds. Teacher educators were from different colleges and operated at different academic levels with their peers at university level. Although there were differences in understanding STEM Education, different groups had the knowledge of what STEM was for the purpose of this study.

4.5.2 Teacher Educator's Competence on STEM Education

Research respondents were offered the opportunity to proffer the competence and skills of teacher educators in STEM subjects they taught. Such perceptions were sought from both the teacher educators and pre-service student teachers. Generally, the competence and skills of teacher educators ranged from very incompetent to extremely competent on a Likert scale. There was consensus between lecturers and student teachers that they were competent and skilled. Generally, lecturers and students agreed that those lecturers who were not competent were a result of lack of resources in teacher education colleges. Figure 15 indicates responses from both teacher educators and pre-service student teachers.

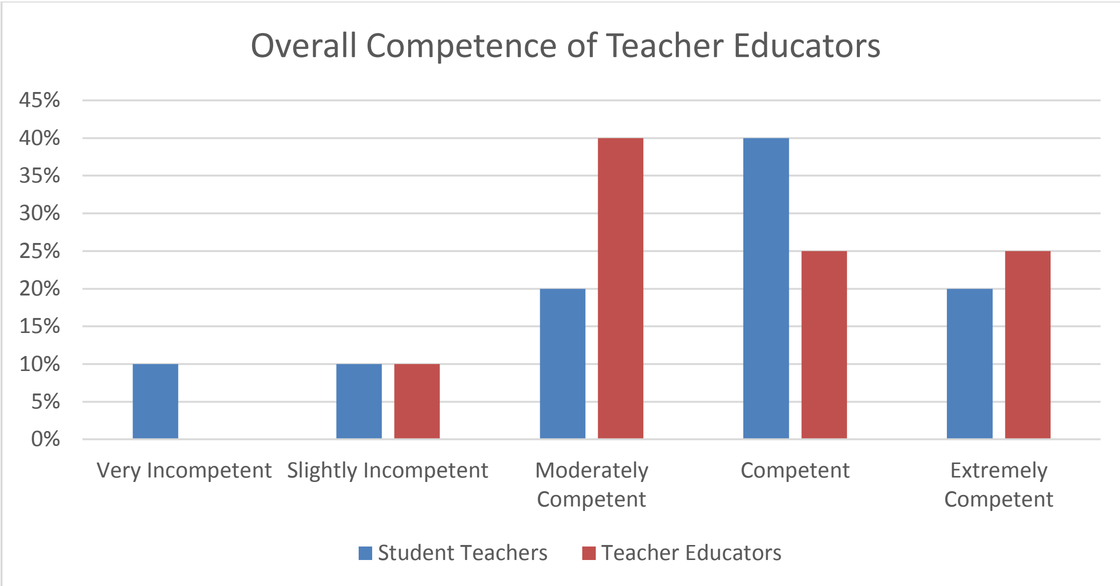

Figure 4. 3 Overall STEM Competences of Teachers Educators

Figure 4.3 shows that most of the teacher educators 95% rated that they were competent and skilled. However, 5% of the teacher educators felt they were incompetent. The teacher educators' measurement of competence was in line with pre-service student teacher determination as acknowledged above. Most of the student teachers perceived that their teacher educators were competent and skilled. Furthermore, data solicited from pre-service student teachers through interviews and focus groups confirmed that lecturers were competent and skilled in teaching STEM subjects. The competence and skills were attributed to the way they presented their lectures. The following were some of the responses represented by lecturers.

CALHSM opined:

> *I have done courses on STEM, written modules on STEM, given assignments, done projects on STEM and presented both papers and lectures on STEM to cluster schools in and around Harare.*

CBL Gonyeti submitted:

> *I am competent through training, that is teacher capacity development and teaching experience. Given the initial training and facilities I had no challenges in developing practical and scientific skills in students.*

Furthermore, CAL Nyamuscom concurred.

> *I have been exposed to technology all my career life in industry and in the Ministry of Education where l developed functional programmes, for companies and institutions and l have also taught Advanced Level Computer Science for more than ten years. I have wealth of experience in technology; therefore, l am competent and skilled to teach technology.*

CBL Machona asserted:

> *I am competent to teach STEM subjects, especially Mathematics. I have a wealth of experience in teaching Mathematics at Advanced Level in the Ministry of Primary and Secondary Education. I joined this ministry 20 years ago. I have been teaching both academic and applied courses in Mathematics. I have been appointed by the University of Zimbabwe, Department of Teacher Education as an external examiner in Mathematics for a couple of years.*

CAL Mashavave opined,

> *I have been a Biology lecturer for 20 years in schools and colleges. I trained as a Biology teacher at Gweru Teachers College. In secondary schools under the Ministry of Primary and Secondary Education I taught Biology to both Ordinary and Advanced Level pupils. I recorded high pass rates than any other teacher in Chegutu District. That experience is worth mentioning. At this college, I introduced Biology after Environmental Science was removed from the primary school curriculum.*

CBL Duncan acknowledged,

> *I feel competent and skilled to teach Chemistry to diploma students here at the college. I was trained to teach Chemistry and I have a degree in Chemistry. The Chemistry content is not an issue. I am well experienced to teach content. I have been a high school Chemistry teacher for years and I have a lot of Chemistry prizes from the Ministry of Primary and Secondary Education in Mashonaland West. These diploma student teachers are benefitting from the*

experience that I acquired when I was teaching Advanced Level Chemistry in the Ministry of Primary and Secondary Education. I have been involved in designing and developing Advanced Level Chemistry syllabus that is currently in use in the Ministry of Primary and Secondary Education in Zimbabwe.

CBL Takawira commented,

Physics is my area by training. I have been teaching Physics in the Ministry of Primary and Secondary Education. When it comes to teaching Physics, I feel competent. The experience that I have was because of teaching Physics at Advanced Level in Murehwa District in Mashonaland East. I am currently Chief Examiner in Physics in the Ministry of Primary and Secondary Education at Advanced Level. Also, I have been appointed external examiner by the University of Zimbabwe, Department of Teacher Education for the past 5 years.

The foregoing comments indicated that most teacher educators were competent and skilled enough to handle STEM subjects. However, the following lecturers indicated otherwise:

CBL Hacksaw had this to say:

I do not feel competent because of inadequate STEM teacher development initiatives. Most lecturers appear good at theory but thin in real life applications. Not enough practical facilities and opportunities are available.

The same sentiments were echoed by CAL Doctor:

Lecturers are not competent because there is need to avail more teaching resources so that integration is made possible.

There was consensus that teacher educators were competent and skilled in STEM Education, although teaching resources were singled out as a barrier to their competence and skills.

4.5.3 Incorporating STEM Education in the Curriculum

On the questionnaire, there was an item soliciting for how teacher educators' incorporated STEM Education in the curriculum. This item was again meant to judge the competence and skills of teacher educators in Education. It was also meant to measure the ingenuity of the teacher educators in designing a STEM syllabus with relevant content and pedagogy. There was general convergence among teacher educators that their current syllabi were focusing on infusing STEM Education which indicated that teacher educators where competent in designing and incorporating STEM education content in their respective STEM disciplines.

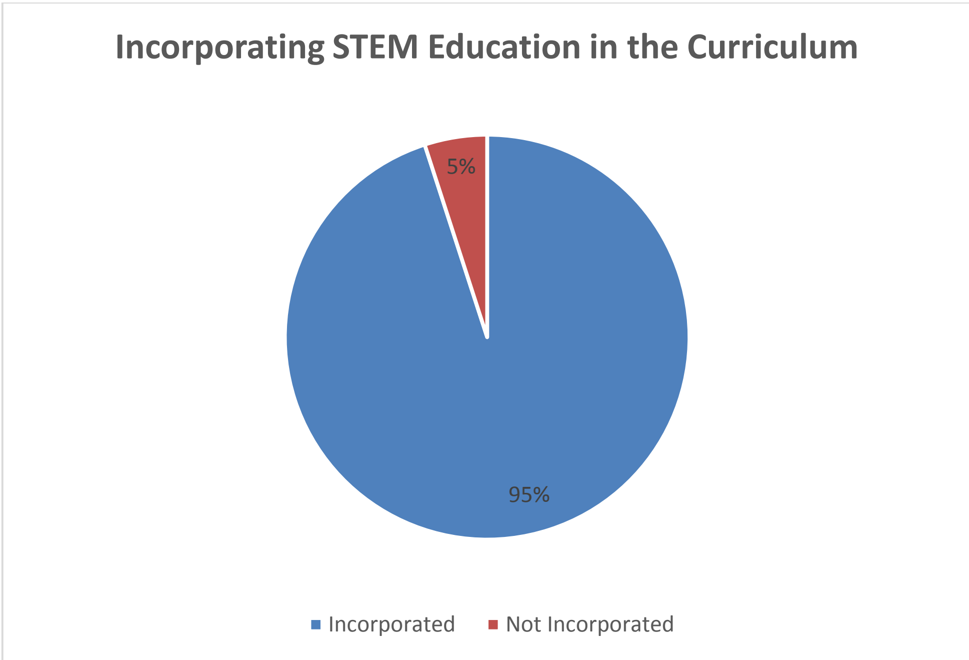

Figure 4. 4 Incorporating STEM Education in the primary teacher education curriculum

Figure 4.4 shows that most teacher educators, 95% rated that they incorporated STEM Education into the curriculum, 5% of the teacher educators felt that they did not incorporate STEM into the curriculum.

The following were sentiments from teacher educators.

CALHSM had this to say:

It has Mathematics, Biology, Chemistry and Physics, and ICT.

CBL Gonyeti echoed:

> *As far as I can remember, there are very few STEM aspects or content that are included in the current syllabus in the new curriculum.*

CAL Takawira acknowledged,

> *In Physics a lot of content was included in the current STEM curriculum. The Physics content included measurements, electricity, and power, among others.*

CBL Duncan alluded,

> *The Chemistry department included a lot of STEM Education content in the Chemistry syllabus. The diploma content for Chemistry is equivalent to first year Bachelor of Education Degree content at university level. Such content included organic Chemistry, experimental Chemistry, periodicity, Chemistry reactions and electrolysis.*

CAL Mashavave commented,

> *We have incorporated a lot of content into the STEM Education curriculum. In Biology, content aspects included were Human Anatomy, Plant Nutrition, and Animal Nutrition, among others. The Biology aspects will assist student teachers in their future studies at university.*

However, reviewed documents painted a different picture from what teacher educators were alluding to. Several STEM subjects, such as, Mathematics were reviewed. The indications were that words like STEM and STEAM were just inscribed in the syllabus, particularly, in Professional Studies Syllabus B, that is, the applied area of STEM subjects. Additionally, in other STEM Education subjects, it was quite silent indeed. One of the teacher educators, CBL Hacksaw alluded that:

> *STEM appears limited to theoretical aspects. The Mathematics syllabus just stated STEM or STEAM Education.*

CBL Hwangwa acknowledged:

In computer science, STEM content was included, it was because of government insisting that colleges should include STEM content in the curriculum.

In the above discourse, it was evident that STEM educators had the capacity to manage STEM content in their respective subjects.

4.5.4 The Utility of STEM Education

The importance of STEM Education to the economy of any country cannot be over emphasized. The importance of STEM reflects the philosophy of the subjects. Teacher educators were asked to reflect on the philosophy of STEM to determine their understanding of the concept. There was convergence on the importance of STEM from various categories of respondents. They acknowledged that STEM Education promoted industrialization, technological development and that it was the backbone of developing and developed countries. The following sentiments were alluded to by teacher educators.

CALHSM had this to say:

> *STEM Education is the backbone of both developing and developed economies. It promotes economic growth and increased opportunities for employment creation and well- rounded learners who are relevant nationally and globally competitive. Furthermore, STEM is a competency-based approach which is practically oriented. It focuses on learner's capacity to apply knowledge, skills and attitudes in an independent and practical way.*

CAL Doctor posited:

> *It promotes technological and industrial development. STEM revolution would be to position Zimbabwe as a giant leader in scientific discoveries and technological breakthroughs and effectively exploit economic opportunities from commercialization of research and development results. It is there for scientific discoveries.*

CBL Gonyeti concurred:

It is a good decision because it promotes industrialization. This is in line with current industrial needs of our country.

CAL Takawira posited,

STEM Education promotes scientific skills in student teachers. The skills will be applied in industry and increase productivity of the country in the long run.

CBL Duncan concurred,

The teaching of STEM Education in teachers' colleges will increase the number of STEM graduates who are going to teach in primary schools, more STEM teachers will be available in the country.

CBL Machona explained,

Zimbabwe is an agro-based nation. STEM Education will increase the number of workers employed in agricultural activities in this country. The skills gained from STEM Education will increase industries in STEM related fields.

On a similar positive note, the student teacher respondents appeared to strongly agree on the importance of STEM Education like their teacher educators.

CBST acknowledged:

STEM will go a long way in empowering the students with skills needed in today's industrial sector and workplace, as an individual, as well as creating employment and boost the economy.

CASTFGD posited:

The teaching and learning of STEM subjects will empower students with skills in their day to day experience. The skills include problem solving, critical thinking, among others.

CAST acknowledged,

STEM Education is important. In countries like United States of America it has led to technological development. It has led to STEM related industries.

CBST echoed,

The teaching of STEM will empower student teachers with skills that are needed for industrial development. STEM will equip student teachers with skills for industrialization. At the same time, STEM Education is for employment creation.

CASTI highlighted,

The teaching of STEM Education will equip learners with 21st Century skills, such as, critical thinking, problem solving, critical judgment and creativity.

In view of the aforesaid, it is prudent to deduce that the teacher educators and the student teachers were aware of the utility of STEM Education. Teacher educator's views were biased towards promoting industrial and technological advancement of the nation. On the other continuum, student teacher's utility was more inclined towards skills development and creation of employment. Therefore, the teacher educators and the student teachers were aware of the utility of STEM Education. It was imperative that the teacher educators had the knowledge of STEM Education and its significance to both industries and the economy in general. Having looked at the teacher educator competencies and skills, the next focus is on teaching methods of STEM.

4.6 The STEM Teaching and Learning Approaches

The second sub-research question for the study sought to establish the teaching and learning approaches used to implement STEM Education in teacher education colleges in Zimbabwe. This was done to establish whether the teaching methods were STEM specific, appropriate were comparable to international best practices. The teaching and learning approaches were solicited mainly through questionnaires, interviews, focus groups and document review.

4.6.1 The Teaching and Learning Approaches Used by Primary Teacher Educators

Teacher educators and student teachers were offered the opportunity to give their perceptions of the STEM teaching methods used by teacher educations under the following Likert scale responses: 1 – Very poor, 2 – Poor, 3 – Fair, 4 – Good, 5 – Very Good. They were asked to justify their ratings. Figure 17 depicted the ratings by both teacher educators and student teachers.

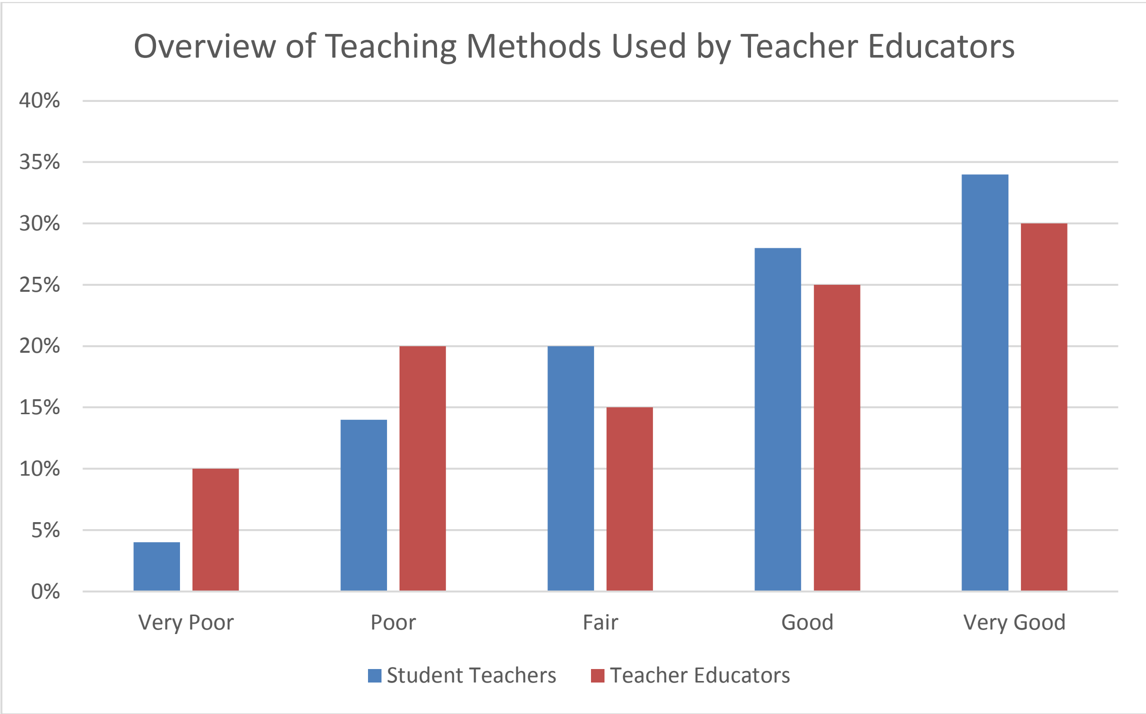

Figure 4. 5 Overall View of Teaching Methods Used by Teacher Educators

Figure 4.5 shows the teacher educator's' responses to the teaching and learning methods used in primary teacher education colleges. The responses were skewed towards very good. The responses had a percentage value of 30%. Respondents, who indicated fair, were 30%, which is a higher figure by any standards to ignore. On the other continuum, 25% of the respondents believed teaching methods were good.

On a positive note, student teacher's responses were also skewed towards very good, just like their teacher educators. The responses were 34%. Respondents who were below 20% and 18% indicated very poor. In view of the foregoing, it was evident that teacher educators STEM teaching methods were skewed towards very good.

4.6.2 Teaching and Learning Approaches Used by Teacher Educators to Teach STEM

The study found it prudent to determine teaching methods used to teach STEM Education in teacher education colleges. Data were solicited on the respondents on the delivery methods used by teacher educators to teach STEM. Data were gathered through questionnaires, interviews, focus groups and document review. The following were narratives on the methods used by teacher educators.

CAL Mashavave explained,

> *Inquiry based learning involves activities of learners, such as, asking questions, planning investigations and reviewing what is known in case of experimental evidence. This is the most recommended method of teaching STEM Education subjects. It involves use of critical and logical thinking in the learners. The learners are engaged in scientifically oriented questions.*

CBL Duncan acknowledged,

> *When using cooperative learning in teaching STEM, everyone in the group contributes and helps, every learner listens to the other group members, learners are motivated, learners would ask for help if need be, group members check if every learner in the group understood and learners should stay in their groups. Learning is collaborative in nature. All these activities entail what cooperative learning is.*

CBL Takawira explained,

> *Field trips or outdoor learning refers to learning activities that are done outside the classroom setup. They take place in the environment. Field trip lessons allow investigation, discovery and experimental learning to take place in the natural setup.*

CHLHSM stated:

The following are some of the methods of teaching STEM; projects, problem solving, and inquiry mode, inter-disciplinary approach, and dialogue.

CBL Humba conceded:

In teaching Science today, the laboratory teaching method is considered practical. Student teachers are given real life problems to solve and conduct observations and experiments, individually or as a group to solve such real-life problems in a laboratory.

CBL Kudakwashe Rombe commented:

In project work, students work or collaborating on the problem or task that they themselves experienced and select to perform. Project work is more inclined to inquiry-based learning.

CBL Hwangwa had this to say:

When using experiment method, there is need to provide an environment that is conducive to the teaching of science. Let the learners observe, and gather information using different tools. The next stage is to analyse the collected data and finally interpret data as they look for solutions to problems.

CBL Prof Logic noted:

Experimentation, problem solving, project method, technical exhibitions and excursions are some of the methods used to teach STEM. These methods call for competency-based approach where skills and values are important.

CAL Nyamuscom opined:

The use of hands on approach where learners are given a chance to experiment, manipulate and observe what they would have learnt during the lesson.

CBL Hacksaw commented:

STEM subjects make use of discovery and inquiry methods.

CAL Kudakwasherombe indicated:

Experimentation, case study, games and debate are some of the teaching methods of STEM

Student teachers had the following perceptions.

CASTFGD indicated:

Concept mapping, problem solving, lab centered instructions, discovery learning, project teaching, and visualizations are some of the methods of teaching STEM Education.

In concurrence with their peers, CBSTFGD identified:

Case study, computer simulation, direct instruction, models, portfolio, presentations, problem-based learning, programmed instructions, reciprocal teaching, role play, and web quest.

Also, CASTFGD acknowledged an array of methods such as:

Demonstration, cooperative/collaborative learning, discussion, experiments, field trips, guest speakers, lectures, problem based, teamwork, discovery, design based, inquiry-based instruction and scientific inquiry.

CBSTFGDs explained,

We use the scientific method or scientific inquiry method. The scientific method has six steps as follows:

1. *Purpose, this is what you want the student to learn.*
2. *Research, students find information in various materials concerning the topic, including internet, and textbooks.*
3. *Hypothesis, students should predict answers to the problem identified. It includes focus of the experiment, conditions of the experiment.*
4. *Experiment, this is done to approve or disapprove the hypothesis.*

5. *Analysis, it involves recording what happened during the experiment phase.*
6. *Conclusion, this involves identifying whether the hypothesis was correct or not. It also identifies what the student learnt during the process.*

On one hand, document review, particularly Science syllabus at CA revealed the following methods under the column methodology: lectures, field trips, problem solving, project design, carrying out experiments, ICT internet, demonstration, drama and storytelling. A further review of ICT syllabus at CB reflected the following methods of teaching: lectures, practical, multimedia, demonstration, discussion and distance education. Additionally, Mathematics syllabus at CA was reviewed and the following were identified as teaching methods: discussions, lecture method, problem solving, peer teaching, micro teaching, distance learning and multimedia.

Based on the evidence provided above by teacher educators, student teachers and document review there was an integration of STEM teaching methods. Most of the methods identified by the three categories of the respondents pointed towards inquiry-based methods. For example, experimentation, problem solving, project-based learning, to mention a few. Inquiry based methods were the in thing in the twenty first century STEM teaching methodology. Therefore, it suffices to say teacher educators and student teachers were aware that teaching methods should be inquiry based. However, being aware and putting into practice are two different issues altogether. Evidence from document reviewed did not suggest that inquiry methods were being practiced by teacher educators. If they were practiced, it was by mere coincidence. Some of the methods were not inquiry based or STEM related, for example, storytelling and micro-teaching to mention just a few. Storytelling is not learner centered methodology; therefore, it does not promote hands on as recommended by the constructivist. Storytelling is more relevant to language subjects than STEM subjects.

4.6.3 Variation of STEM Methods

Student teachers were asked to express an opinion on whether teacher educators differentiated STEM teaching methods from those of other subjects in the college curriculum under the following Likert scale responses. 1 – Not Satisfying, 2 – Slightly

Satisfying, 3 – Moderately Satisfying, 4 – Very Satisfying, 5 – Extremely Satisfying. The student teachers were probed to justify their ratings.

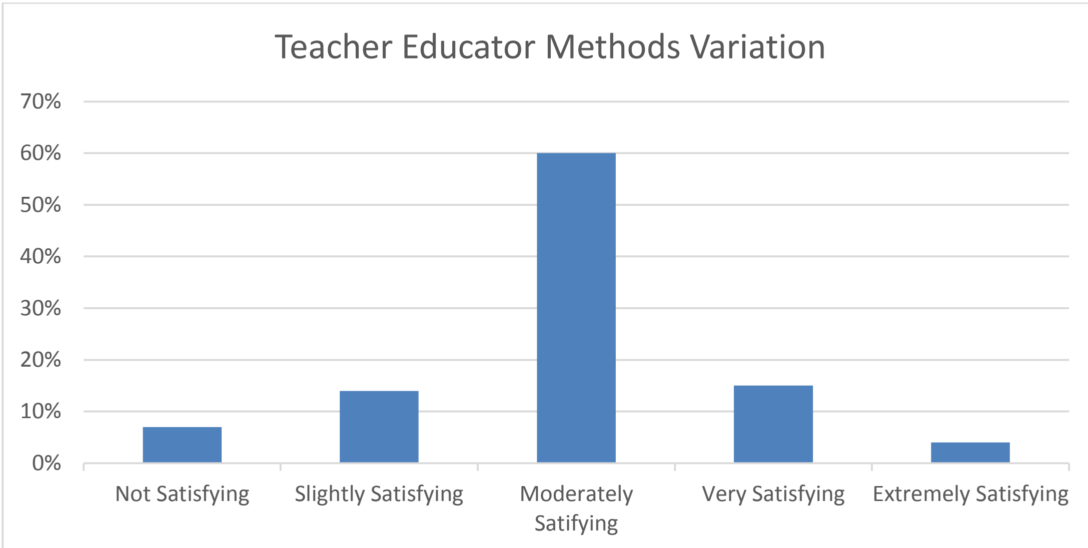

Figure 4. 6 Teacher Educator Methods Variation

Responses from student teachers were skewed towards moderately satisfying (Figure 4.6). The responses had a percentage of 60%. Responses which were below the median were 20%. On the other side of the continuum, that is 20% of the respondents believed teacher educators varied STEM methods extremely well. In view of the above. it was evident that teacher educators were able to teach STEM subjects using specific STEM methodologies. It should be noted that a sizeable number of both lecturers and students had the following reservations about teacher educator’s ability to vary teaching methods.

CBL Prof Logic commented,

> *When teaching STEM Education disciplines, there are teaching methods that are specific to each discipline. The methods include inquiry-based learning, problem based learning and experimental method. These methods assist learners to solve real life problems found in the community.*

CBL Hwangwa acknowledged,

> *Selection of teaching method should consider the subject being taught and the learners since learners have different learning styles. Therefore, as teacher*

educators, we should take note of the student teacher's learning characteristics when choosing teaching methods. Learners by nature are different, some learn by seeing, hearing and observing. Therefore, teaching methods should cater for learner diversity.

CBL Hacksaw had this to say,

The essence of an effective teacher is seen normally through selection of teaching methods. Teaching methods determine the success of a lesson. As teacher educators, we differentiate STEM teaching methods to cater for individual differences between and among students.

CBL Machona commented,

The teaching methods for STEM Education are different from those obtaining in other subjects. Teaching methods in Mathematics are different to those of Chishona. As a result, there is need to show that difference through selection of teaching methods that are specific to Mathematics.

CASTFGD commented:

Lecturers sometimes use experiments occasionally and they also use different strategies from other subjects.

CBSTFGD echoed:

Some strategies in the teaching of other subjects in the primary curriculum are not applicable to STEM lessons for example, storytelling and role play.

CASTI sums it up:

When teaching STEM subjects, they use progressive teaching methods whereas traditional methods are used on other subjects in the primary curriculum.

CAST2I commented,

> *Our lecturers used inquiry-based teaching methods. The STEM Education calls for inquiry-based teaching methods. Such inquiry-based teaching methods include guided discovery, unguided discovery and project-based methods.*

CBST3I had this to say,

> *During Mathematics lectures, we are exposed to problem solving activities. The problem-solving activities are related to what we encounter in our daily activities. The problem-solving activities assist us to be real problem solvers in life.*

CAST4I acknowledged,

> *The Chemistry lecturers are creative; they expose us to field trips where we visit chemical industries such as ZIMFORCE in Harare. There is processing of fertilizer. The process is quite complex. Through such field trips, learning of STEM Education, particularly, Chemistry has been made easy.*

CAST3I commented,

> *Our lecturers in Computer Science differentiated teaching methods. We are exposed to computer simulations and project-based learning. The learner is expected to produce a product after every lecture. This method is specific to the STEM Education disciplines and Computer Science in particular.*

CBST4 had this to say,

> *In Biology, our lecturers use problem solving and inquiry-based learning methods. These methods are specific to the teaching of STEM Education, especially Biology. Such methods help us to understand Biology.*

Based on the evidence postulated above, it was prudent to deduce that teacher educators differentiated STEM methods from those that were obtaining in other subjects in the college curriculum. However, there were tendencies to fall back on methods that were not STEM specific. This could have been attributed to some of the teacher educators who had been in the profession for a couple of years who could not quickly adjust to the current trends in STEM teaching.

4.6.4 The Use of STEM Teaching and Learning Approaches During Teaching Practice

The use of STEM teaching methods during teaching practice was an area of interest. This was meant to assess the application of theory into practice by student teachers. It was also meant to measure the methodologies they had learnt at college. Teacher educators and student teachers were well placed to give an accurate assessment probably based on their responsibilities and experience. Figure 19 depicts responses from both teacher educators and student teachers.

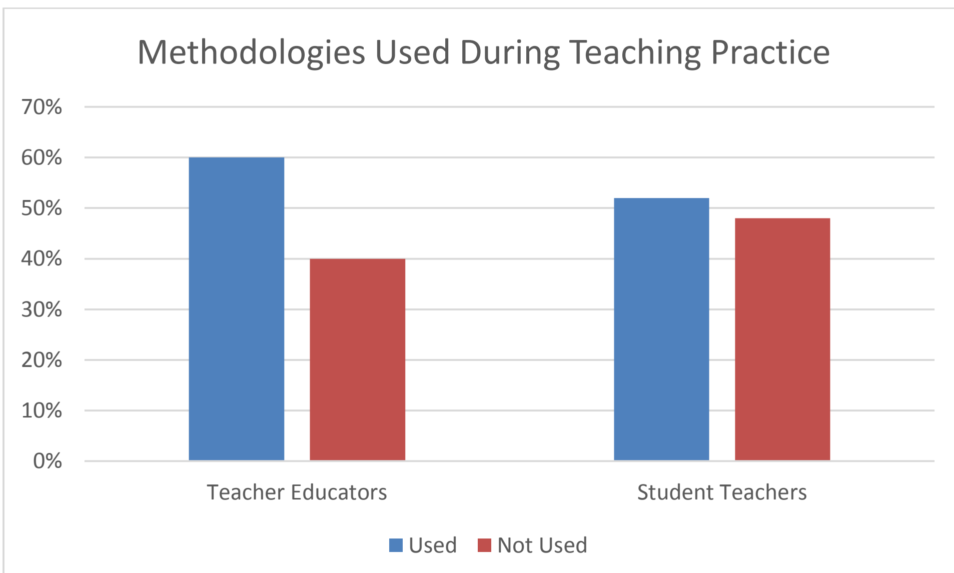

Figure 4. 7 Teaching and Learning Approaches Used by Pre-service Teachers During Teaching Practice

As shown in Figure 4.7, most of the teacher educators, 60%, indicated that student teachers used STEM methodologies during teaching practice, whereas 40% stated that STEM methods were not used. In agreement, student teachers 52% stated that STEM methods were used, while 48% denied. The following narratives from student teachers indicated that they did not use STEM methods during teaching practice.

CBL Duncan posited,

I went for teaching practice in Murehwa to supervise intake 46. I was really impressed by our student teachers' performance. They were able to apply teaching methods taught at college very well, especially, problem-based learning, field trips and project-based learning. The little learners they were teaching were able to produce products from the lessons taught. These student teachers are quite creative. I hope they will still do that after completing the diploma course.

CBL Kudakwasherombe had this to say,

During teaching practice supervision, the student teachers I observed used teaching methods they were equipped with at this college during their first residential course. They successfully applied field trips and problem-based learning during teaching practice. The lesson that I observed made use of field trips to a nearby mountain, this was quite amazing.

CBL Hacksaw alluded,

I made several visits to student teachers in Mashonaland West and Central. I was quite impressed that our student teachers were able to use teaching strategies we taught them here at college. They did it perfectly well, especially guided inquiry when they were teaching Science and Technology.

CASTI highlighted:

I used STEM strategies that I was equipped with at college during my teaching practice. There were laboratories for carrying out experiments.

CBSTI added:

I used the field trips during teaching practice because the administrators allowed teachers and learners to go for field trips as they put much concern on the academic issue of the learners.

CBSTI acknowledged:

At the school where I was practicing, I used experiment because the facilitator learner ratio was low. Imagine a class of 20 to 30 learners using experimental method. This would be next to impossible.

CAST1I commented,

I was deployed in Murehwa district in Mashonaland East Province. At the school where I was teaching, I used guided inquiry method to teach Science and Technology at primary school. The learners enjoyed the lessons especially on the topic Materials in Technology.

CBST2Is echoed,

I was deployed in Mashonaland Central province, Mazowe District. I used several teaching methods that we were taught at college during Professional Studies Syllabus B lectures. Some of the methods I used included field trips, problem solving, experiment, guided and unguided. In Mathematics, problem solving was quite useful.

CBST1I substantiated,

At Chirorodziva Primary School where I was deployed, I applied the teaching strategies that we were equipped with at college. Learners enjoyed field trips in and around the school. Project method was also used during teaching practice. Learners enjoyed producing products which they took home after the lessons.

CASTI explained,

I was deployed in Harare Province, Mbare, Hatfield District. I used the methods we were taught at college during our first residential. Learners *enjoyed experiments carried out in the school garden. They investigated how plants manufactured their own food in the school garden.*

CBSTI commented,

> *I was deployed in Chivhu in Mashonaland East Province. During Computer Science lessons in the computer laboratory I used the project method to teach learners. The learners really enjoyed the computer lessons. During Mathematics lessons I used problem solving mostly. This method is more applicable to Mathematics.*

CAST opined,

> *I was doing teaching practice in Mhondoro, Mubaira in Mashonaland West. I used a lot of teaching methods that we were equipped with at college during our first residential course. When you are out there, you also experiment on some of the methods. Learners really benefitted from the use of the teaching methods I applied during teaching practice.*

This implied that STEM methods were being used during teaching practice by student teachers. There was overwhelming evidence that student teachers did apply the theories they learnt at college during teaching practice.

4.6.5 Appropriateness of STEM Teaching Methods

Teaching methods should be relevant, meaningful, and appropriate. Teaching methods should encompass quality and subject specific attributes. Respondents were asked to express their opinions on efficiency of teaching methods. There were variations on their responses. Teacher educators and student teachers were best placed to assess adequacy of teaching methods as they were always working with them. Figure 4.8 shows student teachers and teacher educators' assessment of adequacy of teaching methods.

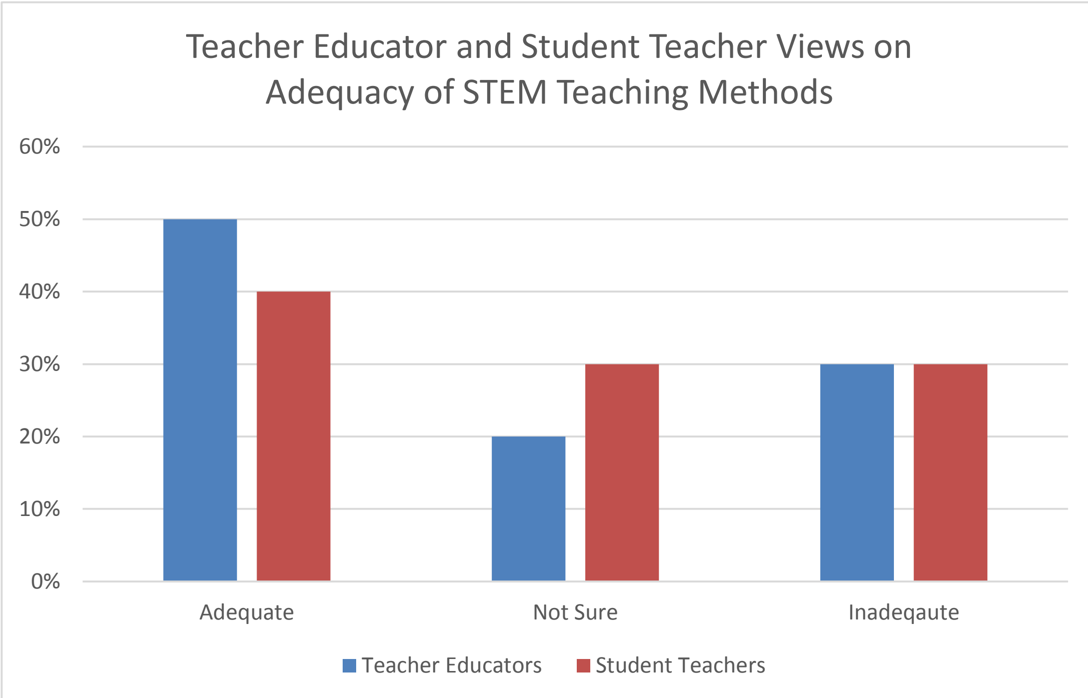

Figure 4. 8 Teacher Educator and Student Teacher Views on Adequacy of STEM Teaching Methods

The results indicate that 50% of teacher educators rated the STEM teaching methods as adequate in the context of being specific and serving the purpose they were supposed to serve. The adequacy also translated to methods being inquiry focused, user friendly and learner specific. From the students' perspective, adequacy was below 50%, that is, 40% of the respondents. This was not convincing. This variation in responses was acknowledged in the following verbatim quotation from teacher educators:

CALIHSM acknowledged,

> *In the Mathematics Department, we expose our student teachers to several teaching strategies. I can confirm to you that the teaching strategies that Mathematics student teachers are exposed to are more than enough. The teaching methods are adequate.*

CBLFGD commented,

The teaching methods used in different STEM disciplines are adequate at this college. We believe that STEM Education methods are basically inquiry based. The student teachers are being equipped with such methods. These include problem solving, project method, and experimentation, among others.

CBL Duncan acknowledged,

In the Chemistry Department we expose our student teachers to several teaching methods. The teaching methods are all inquiry based.

CBLI Kudakwasherombe,

As a Computer Science lecturer, the teaching methods that are available for teaching Computer Science are adequate. The student teachers are exposed to a variety of teaching strategies. These student teachers are benefitting from the methods they are being exposed to.

CALI Nyamscom had this to say,

As you are aware, when teaching a particular concept or lesson you can use many teaching methods in one lesson. In Computer Science, the teaching methods are adequate. In fact, they are more than adequate. Our student teachers are benefitting from the various teaching methods we exposed them to.

CALFGD lamented:

The adequacy is compromised due to lack of required facilities and resources needed for effective implementation of these strategies.

CBLI Prof Logic commented:

The methods/strategies are satisfactory, only that there is need to avail resources so that trainees can effectively benefit from the teaching strategies.

CBLI Kudakwasherombe lamented:

The strategies are inadequate because there are shortages of materials and financial resources.

CALI Nyamuscom sums it all:

The strategies are okay given proper working space, equipment for demonstration and practical.

However, CBL Machona lamented,

As far as I am concerned, the teaching methods were not adequate as the laboratory approach was not employed by teacher educators. The laboratory approach was not used as there were no consumables for the experiments. In most cases, teacher educators relied on theory. Experiments were done here and there.

Based on the discourse above, the teacher educators and student teachers seemingly agreed that the STEM teaching methods were adequate. The only point of departure was pointing towards shortage of resources, some of the STEM teaching methods required a lot of financial resources for them to be used effectively and efficiently, for instance, experimentation and project-based learning. The next discussion is on resources, facilities and support system in teacher education colleges in Zimbabwe.

4.7 Resources, Facilities and Support System in Teacher Education Colleges

Resources, facilities and support are key enablers in the provision of quality of education. The successful implementation of any curriculum innovation hinges on facilities, such as, libraries, laboratories, lecture rooms, and multimedia centers, among others. Their availability, adequacy and quality were fundamental to STEM Education in teacher education colleges. The support rendered by different stakeholders was critical in ensuring successful implementation of STEM Education. The resources, facilities and support, formed the third sub-research question for this study. Focus was on the availability and adequacy of laboratories and libraries.

4.7.1 Availability of Libraries in Teacher Education

The importance of libraries in any institution of higher learning cannot be overemphasized. Teacher educators and student teachers were the main respondents of this critical issue of resources and facilities. It was established that college libraries were well stocked with e-journals. The colleges made subscriptions to several e-journals that included SAGE, JOST, Francis Taylor, EBSCO Host and Emerald. It was noted however with concern that STEM textbooks written this decade were in short supply in the libraries. The few that were there were inadequate for the number of STEM Education student teachers in their final year and those on teaching practice (TP).

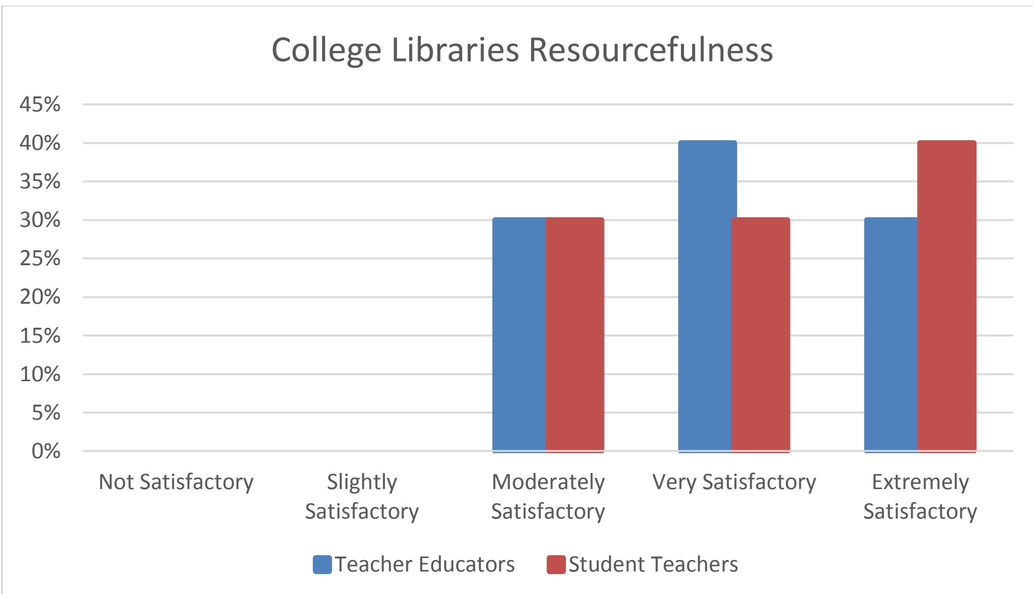

Figure 4. 9 College Libraries' Resourcefulness

As depicted in Figure 4.9, teacher educators and student teachers agreed that college libraries at both institutions were well resourced. The resources were rated very satisfactory by 40% (n=8) of the teacher educators and 30% (n=15) indicated that they were extremely satisfactory. On the other hand, student teachers also agreed that 30% (n=15) of the resources were very satisfactory and 40% perceived the facilities as extremely satisfactory. Furthermore, below are qualitative data responses indicating participant's perceptions on college library as a resource.

CALIHSM asserted:

> *The college has a digital library for research and development, pre-service learners are given a chance to use the library while on teaching practice and on residential (on campus*).

CBLI Kudakwasherombe noted:

> *Our library is well stocked with up to date books and student teachers have a lot of access to e-journals that are in abundance.*

CALI Hamadzangu:

> *The college library is well established with multimedia technology center, which is very functional.*

CBLI Haranga:

> *The college library is well stocked with full ICT equipment, projectors and unlimited computer services.*

CBL Hwangwa acknowledged:

> *The college library is well stocked with e-journals SAGE, JOST, Francis Taylor, EBSCO Host and Emerald. These journals are current.*

4.7.2 Accessibility of the Library

The library's resources in teacher education should be available to student teachers at any given time. Teacher educators and student teachers were the main respondents on accessibility of libraries. The questionnaire solicited data through five-point Likert scale responses. 1 – very inaccessible, 2 – slightly accessible, 3 – moderately accessible, 4 – very accessible, 5 – extremely accessible.

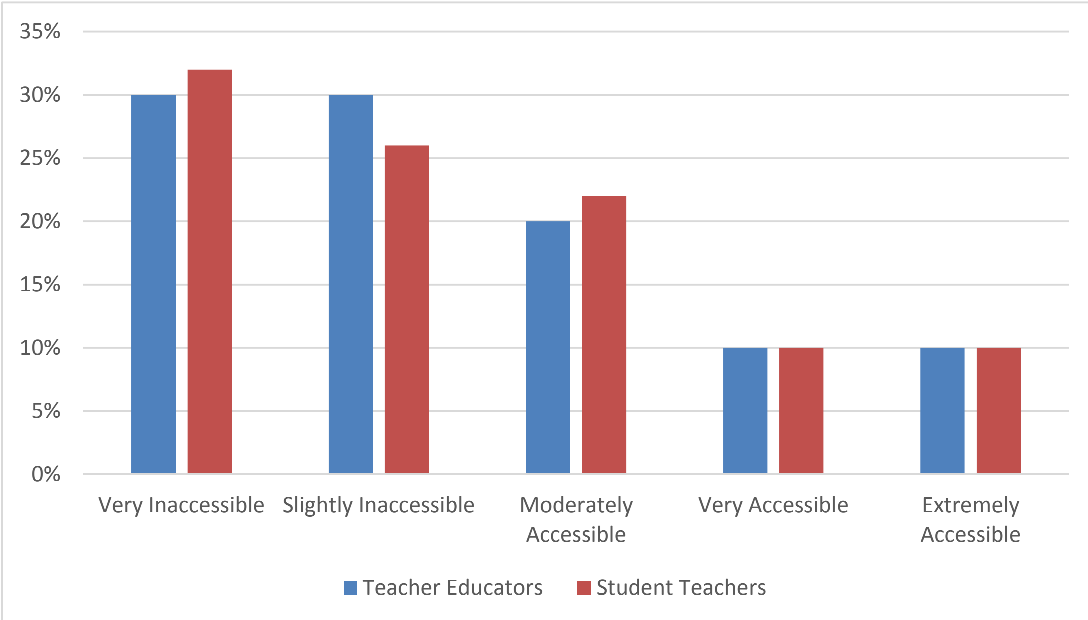

Figure 4. 10 Accessibility of the Library

Figure 4.10 depicts that teacher educators and student teachers agreed that the library as a resource was not accessible to student teachers and teacher educators. Most of the teacher educators 60% disagreed that libraries were accessible. Student teachers 67% concurred that libraries were not accessible to its clients. Student teachers and teacher educators could not access the library because it was closed due to power outages and it was used as a lecture room by Early Childhood Development student teachers. The following were narratives of the participants.

CBLI Hacksaw acknowledged:

> *The libraries in teachers' colleges are well stocked. However, the most important issue about a library is its accessibility to the clients. In teachers' colleges, libraries are open from 08:00 to 18:00 every day except on Saturday where they are opened from 08:00 to 13:00. The timetable for student teachers' lectures was from 8 00 to 13:30. In the afternoon, it was from 14:30 to 16:30. During the day, student teachers are not allowed into the library during lecture times. Student teachers are only allowed into the library between 13:30 and 14:30 and that will be during lunch time. After 16:30 most of the students leave the college because most of them are*

non-resident. Only a few resident students would have access to the library that is if electricity is available on that day.

CAL Humba commented:

> *Currently in Zimbabwe there are power outages. These current affairs are affecting both student teachers and teacher educators in accessing the library. The library has been digitalized, therefore, when there are power outages, the library will be closed.*

CBL Mahingi had this to say:

> *The teachers' colleges are being affected by power outages, especially the libraries. The colleges cannot afford alternative sources of power because they are expensive. The generators available need diesel. Diesel is currently in short supply and expensive. As a result, when there are power outages the libraries are technically closed.*

CASTI opined:

> *The timetable at our college is congested. There are no free periods for research in the library. The library is closed when there is a power outage.*

CBSTI alluded:

> *I am a non-resident. I cannot afford to stay at college because of financial challenges. I fail to access the library during the day because I will be attending lectures.*

At CB, student teachers complained that part of the college library was used as a lecture room for the Early Childhood Development (ECD Students).

In the foregoing discourse, various participants acknowledged that the college libraries were not accessible to student teachers and teacher educators. There were several factors that militated against accessibility of the library. Student teachers acknowledged congested timetable, power outages and the issue of them being nonresident students.

More so, at CB students observed that the library was being used as a lecture room for ECD. Such observations were a cause for concern as student teachers ended up scrambling for space on one corner of the library. The student teachers research time were thus limited while ECD lectures were in progress. As such, there was a lot of interference and divided attention on the part of student teachers during ECD lectures in the library.

All these factors point to the library being inaccessible to both student teachers and teacher educators.

4.7.3 Adequacy of Laboratories at Teacher Education Colleges

Laboratories are an enabler in the teaching and learning of STEM subjects. Experiments, designs, models and prototype are all developed in functional laboratories. The study wanted to establish the availability, adequacy and functionality of laboratories in teacher education colleges. The responses were solicited from teacher educators, student teachers, university lecturers and directors.

4.7.3.1 Adequacy of Laboratories

Teacher educators and student teachers were asked to rate the adequacy and functionality of laboratories. The questionnaire item solicited data through five-point Likert scale responses as 1 – Very Inadequate, 2 – Slightly Inadequate, 3 – Moderately Adequate, 4 – Adequate, and 5- Extremely Adequate.

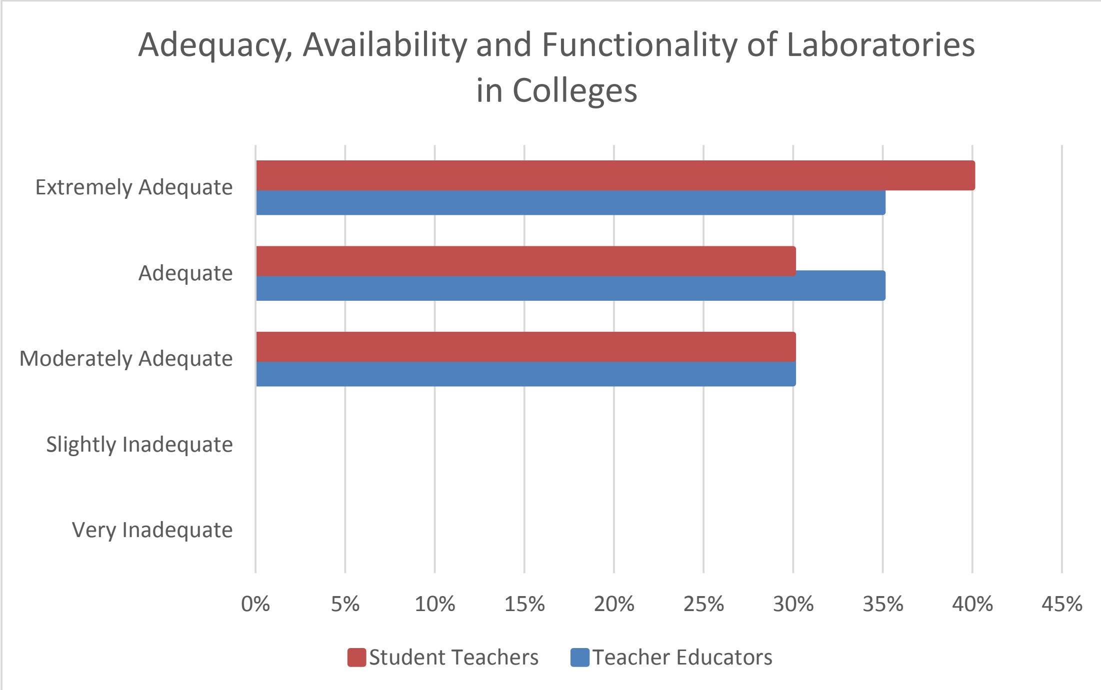

Figure 4. 12 Adequacy, Availability and Functionality of Laboratories in Colleges

Figure 4.12 shows that teacher educators agreed that laboratories were available and adequate as well as functional. Most of the teacher educators 70% (n=14) acknowledged that laboratories were adequate and functional. On a similar note, student teachers, 72% (n=36) concurred the availability, adequacy and functionality of laboratories in teacher education colleges. The following were qualitative responses from participants about availability, adequacy and functionality of laboratories in teacher education colleges.

CALI Marongwe commented

> *The college has two computer laboratories, two science laboratories, an electronic library and a multi-media center.*

CALI Tirivangani concurred:

> *There are established laboratories, Educational Media Technology Centre and use of ICT in teaching.*

CALI Humba acknowledged:

> *There are limited facilities. The computers laboratory is functional even though sometimes there are few computers working*.

The discourse points to the adequacy of the laboratories in different STEM disciplines, such as, Computer Science, Chemistry, Physics and Biology. The laboratory resource for implementing STEM strategies was available and adequate in teacher education colleges.

4.7.3.2 Functionality of the laboratory

Teacher educators and student teachers were asked to assess the functionality of the laboratories in teachers' colleges. The questionnaire item solicited data through five-point Likert scale responses as 1 – Not Functional, 2 – Slightly Functional, 3 – Moderately Functional, 4 – Functional, 5 – Overly Functional.

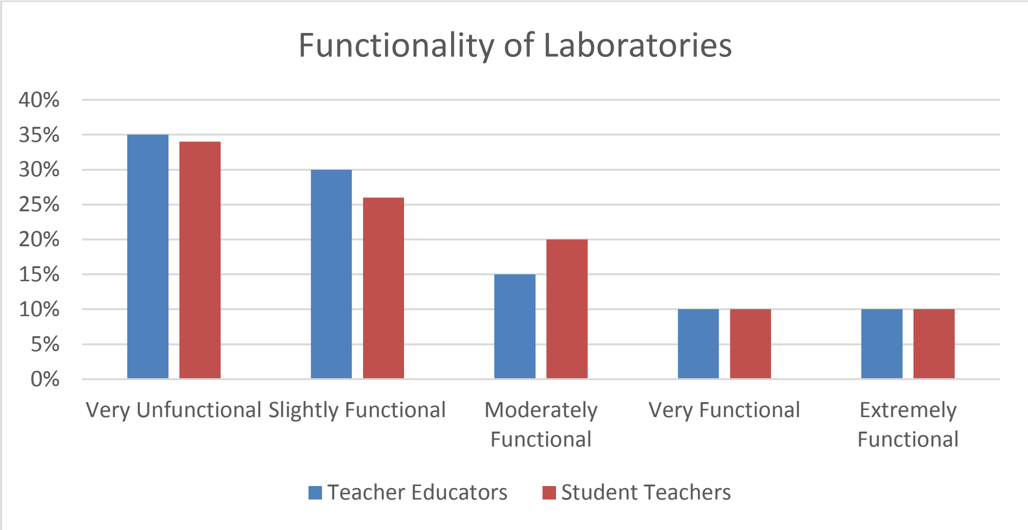

Figure 4. 13 Functionality of Laboratories

Figure 4.13 shows that teacher educators disagreed that laboratories were functional. Most of the teacher educators 65% disagreed that laboratories were functional. On a similar note, student teachers 60% concurred that laboratories were not functional in teacher education colleges. The following were narratives from participants about functionality of laboratories in teacher education colleges.

Lecturers in FGD describing the laboratory indicated:

This college used to be a high school prior to independence in 1980. The high school was converted, part of it, into a teacher's college and other parts remained as a high school. The high school laboratories remained on the high school side. Currently the teachers' college is using a classroom that used to be a lecture room for Chishona as a laboratory. There is nothing in the makeshift laboratory as no meaningful experiments can be carried out in the laboratory

DHO1 echoed:

In teachers' colleges there is shortage of laboratories, equipment, chemicals and other paraphernalia associated with STEM Education.

The ULI commented:

The learning environment for science is not conducive because of the economic situation in the country. Secondly, there is a dearth of infrastructure that supports Science in teachers' colleges.

CBL Prof Logic acknowledged:

The available laboratories do not have chemicals, apparatus, equipment, beakers, among others. Most of the lectures conducted in the laboratories were mere theory. There was no provision for practical.

A document review of Chemistry final examination question paper revealed that it was a three-hour theory paper and was never complemented by a practical paper.

CBL Duncan had this to says,

The Chemistry laboratory at this college was constructed after independence in 1980. The only challenge with this laboratory is that there are no consumables for practical. It is almost 2 years without Chemistry consumables in the laboratory. We cannot conduct experiments in the laboratory. The student teachers doing Chemistry are being disadvantaged because of this situation. The Chemistry laboratory is not functional.

CAL Mashavave echoed,

> *The Biology department has the best state of the art laboratory in the province. Our only challenge is that the laboratory is poorly resourced as there are no basic Biology consumables for practical activities. The consumables are procured intermittently. In most cases they are not available. The laboratory is not well resourced. Experiments cannot be done so often. This affects STEM student teachers doing Biology at this college.*

CBL Takawira acknowledged,

> *The Physics laboratory at this college is not functional as experiments are not being done in the laboratory. The Physics consumables are expensive to procure. The college is failing to procure because of lack of financial resources.*

In an interface with student teachers, indications were that student teachers and teacher educators conducted lectures in the same manner English Language was conducted. Student teachers complained that they found Chemistry difficult because they were not exposed to practical activities in laboratories.

Based on the aforesaid discussion, all the participants agreed that laboratories at the two teacher education colleges were not functional. The inefficiency of the laboratories was attributed to lack of laboratory consumables. As such, experiments and laboratory practical activities could not be carried out. Student teachers raised alarm that in Chemistry there were no practical. It was only theory. Chemistry was being taught like any other subject in the curriculum. This concern was more revealing in terms of the functionality of the laboratories.

4.7.4 Available interactive whiteboard resource

Teacher educators and student teachers were the main respondents on the availability of the interactive whiteboard. The questionnaire solicited data through 3-point Likert scale, 1 – Not Available, 2 – Not Sure, 3 – Available.

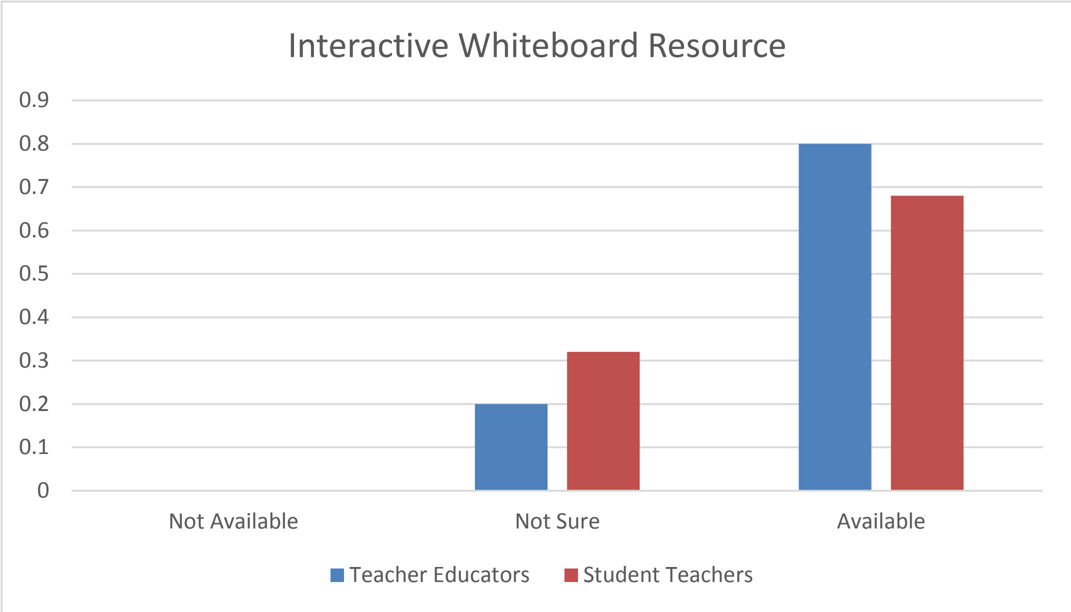

Figure 4. 14 Available Interactive Whiteboard Resource

Figure 4.14 depicts that teacher educators and student teachers agreed that the interactive whiteboard was available in teacher education colleges. Most of the teacher educators 80% agreed that the interactive whiteboard was available. Student teachers 68% concurred that the interactive whiteboard was available in teacher's colleges as a teaching and learning resource. The following were narratives of the participants.

CBL Machona acknowledged,

> *In our department we have an interactive whiteboard for use by both student teachers and teacher educators. The interactive whiteboard was installed a year ago.*

CBL Duncan echoed,

> *In the Chemistry department the college installed an interactive whiteboard for the purpose of teaching and learning Chemistry. This resource is available to both student teachers and teacher educators. It is good because it makes learning interactive. It caters for different learning styles of our students.*

CAL Takawira had this to say,

> *The existence of interactive whiteboards in the college is a noble idea. The interactive whiteboard in our department is for both student teachers and teacher educators. It is a resource that makes learning effective and efficient.*

CALHSM acknowledged,

> *We have an interactive whiteboard in the Mathematics department. This facility was installed by the college. The resource is available for both student teachers and teacher educators. The interactive whiteboard is specifically for Mathematics. We are happy to have such as modern facility in the department. The Vice Principal was so enthusiastic about the interactive whiteboard in the college.*

CBST2I alluded,

> *I am specializing in Mathematics at this college. We have an interactive whiteboard specifically for the teaching and learning of Mathematics in the college. This interactive whiteboard is for use by all student teachers doing Mathematics at this college.*

CAST3 acknowledged,

> *In the Chemistry department we have an interactive whiteboard at our disposal. The interactive whiteboard is for use by both student teachers and teacher educators. The facility had made the teaching and learning of Chemistry interesting.*

CBST3I said,

> *The college has several interactive whiteboards for use by different departments. Each STEM department has an interactive whiteboard. It has helped in the teaching and learning of STEM Education in the college.*

4.7.5 Availability of STEM Textbooks in Teacher Education Colleges

Textbooks are a key resource to the implementation of STEM Education. They ensure effective and efficient delivery of STEM Education in teachers' colleges. It goes without saying that textbooks enable teacher educators and student teachers to sharpen their research skills in STEM subjects. Textbooks provide student teachers with an opportunity to exercise reflective thinking and critical judgment. These are prerequisite skills for STEM. This study sought to establish the availability of STEM textbooks in teacher education colleges in Zimbabwe.

The respondents were teacher educators and student teachers. They confirmed that STEM textbooks were available in teacher education colleges. The availability of textbooks meant that, student teachers benefited in the long run. However, Mathematics and science departments complained that textbooks were not adequate to the student population that was available in colleges. The following pie charts relate to the availability of textbooks in teacher's college.

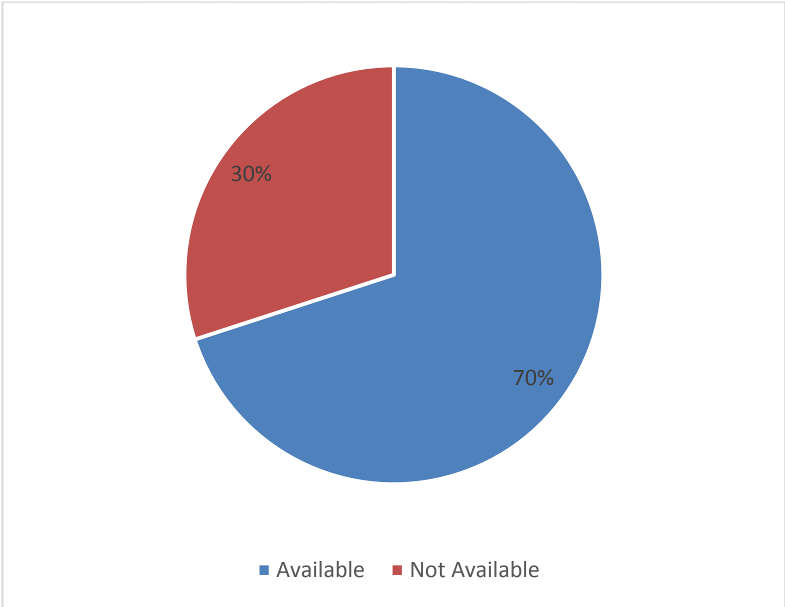

Figure 4. 15 Teacher Educators' views on availability of STEM Textbook in Teachers' Colleges

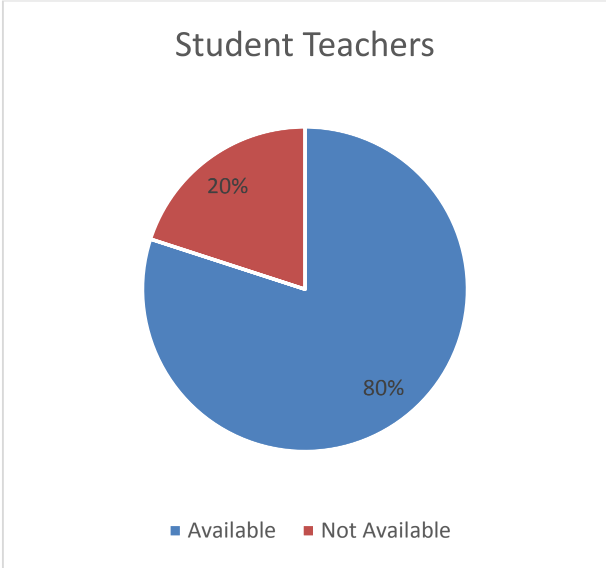

Figure 4. 16 Student Teachers' views on availability of STEM Textbook in Teachers' Colleges

The pie charts above (Figures 4.15 and 4.16) indicate that the STEM textbooks were available in teachers' colleges. Most of the teacher educators 70% and 80% of student teachers agreed that STEM textbooks were available in teachers' colleges. On the other end of the continuum, 30% of teacher educators and 20% of student teachers thought textbooks were not available.

Further to this end, one of the lecturers, CALIHSM gave the following narrative.

> *Textbooks are sometimes seen as a key determinant of learning outcomes. In Science and Mathematics, they are particularly important for both teachers and students as they are the main teaching resources. The Science and Mathematics textbooks are inadequate, and, in some cases, they are not available. In our Mathematics Department the student-textbook ratio is very high. This is a cause for concern.*

CBSTFGD concurred,

> *There is shortage of textbooks in most colleges. Colleges have not yet acquired the Science and Technology resources for the new curriculum. In some instances, student teachers use one copy for reference purposes.*

CAL Marongwe commented:

The Biology department has limited number of textbooks in relation to the number of student population at the college. The situation becomes dire when we give student teachers assignments. They scramble for the limited textbooks in the library.

CASTI alluded:

At our college there are limited Biology textbooks. The limited textbooks affect us when writing assignments. At the end of the day, many of us end up doing cutting and pasting of assignments to meet the due date.

CBL Humba indicated:

Textbooks were available. However, they might not be current to meet the twenty-first century skills and content for STEM Education. Some of the textbooks were considered outdated for STEM.

CBL Munengwa indicated

There were enough textbooks in the Computer Science department. The available textbooks are current and up to date. In the Computer Science department, students have a wide choice of textbooks.

CAL Mahembe echoed the same sentiments:

The Physics department is well stocked with textbooks. We have different textbooks from different publishing houses.

Based on the above discourse, teacher educators and student teachers seemingly agreed that there were enough textbooks in teacher education colleges. The Computer Science and Physics departments were well stocked with textbooks that were current and up to date. Computer Science and Physics students had a variety of textbooks for their research and assignments. However, the Mathematics and Biology departments had textbooks, but they were limited in relation to student population at the colleges. The issues of limited textbooks in Mathematics and Biology affected student teachers during assignment writing. Student teachers scrambled for textbooks. As such student teachers would end up copying each other's assignments. One assignment circulating among the whole intake. Having said that, it was prudent to deduce that textbooks were available in Physics and Computer Science Departments. On the other hand, textbooks were in short supply in Mathematics and Biology Departments because of high student population in those STEM disciplines.

4.7.6 Support Rendered to Teacher Education Colleges

Support provided by different stakeholder is key to the successful implementation of any curriculum initiative. Teacher educators and student teachers were asked to assess whether teachers' colleges were rendered support by different stakeholders. Different stakeholders supported teacher education colleges through workshops for professional development and construction of infrastructure for stem education. The results were as shown in the Figure 4.17 below.

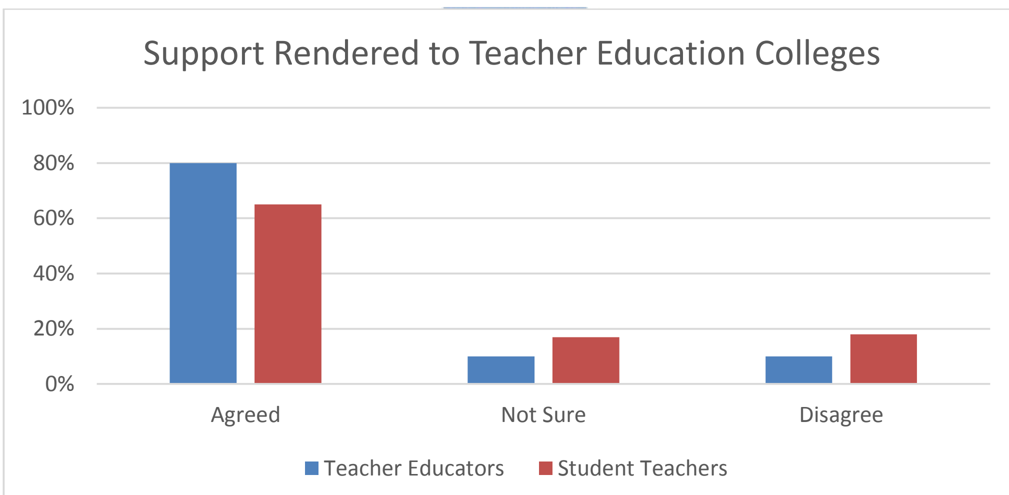

Figure 4. 17 Support Rendered to Teacher Education Colleges

Eighty percent (80%) of teacher educators agreed and 65% of student teachers concurred that teacher education colleges received support from different stakeholders. There was overwhelming evidence that teachers' colleges received support from different stakeholders.

Furthermore, DHOI2 commented:

Different stakeholders are supporting teacher's colleges through donating some materials, labour, computers, ICT tools, and chemicals for experimenting. There are also awareness campaigns from different stakeholders as well as financial support to implement STEM Education in teachers' colleges and schools.

CALHSM indicated:

This college is very fortunate in that several stakeholders are supporting it in various areas. The computer laboratory was constructed through donations of building materials and labour. The computers in that laboratory were donated by well-wishers.

CBL Haranga echoed the same sentiments:

The college has received support from numerous players. This institution received Physics and Computer Science textbooks from prominent community members. The former student board donated laptops for the lecturers in charge of Physics, Mathematics, Computer Science, Chemistry and Biology.

CBL Kudakwasherombe observed:

The college finance committee (CFC) was helping departments acquire the necessary materials for STEM Education particularly, consumables in Biology, Chemistry and Physics.

In the aforesaid discussion, different participants seemingly agreed that there were various stakeholders who were supporting the colleges. The support was in the form of construction materials, labour, computers, textbooks and laptops. The construction of computer laboratory enhanced the teaching of Computer Science in colleges. Also, the donation of computers went a long way in promoting STEM Education in colleges.

4.7.7 Provision of Workshops

In teacher education, workshops are part of Professional Development (PD) for teacher educators. Examples of such workshops include research skills trainings, STEM content selection and Information and Communication Technology skills trainings. During such workshops, iron sharpens another iron. Ultimately, there is growth in terms of professional skills. Teacher educators, directors and university lecturers were the respondents. They unanimously agreed that workshops were sponsored by different stakeholders. During such workshops, different stakeholders provided training venues, meals, bus fare and accommodation if they were held outside Harare province. The figure below indicates the provision of STEM workshops.

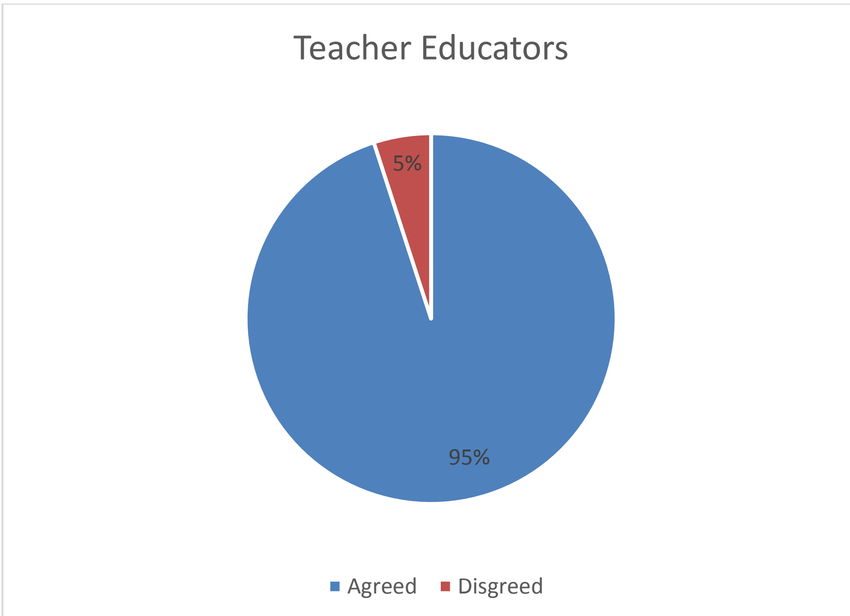

Figure 4. 18 Provision of STEM workshops

As reflected in Figure 4.18 above, 95% of the teacher educators agreed that there were workshops sponsored by different stakeholders, while 5% disagreed. The following is a narrative of qualitative data by a participant.

DHOI2 commented:

> *There have been numerous attempts to train teachers in the use of ICT, perhaps most notably UNESCO's teacher training in Africa. Teachers are trained in ICT in teachers' colleges. UNESCO pays the facilitators and provides resources for the training. Recently there was a workshop funded by UNESCO at Masvingo Teachers' College where a sizeable group of teachers were exposed to ICT training.*

CBL Prof Logic acknowledged:

> *The science and Mathematics departments had a workshop held at Bindura University of Science Education. At this workshop, Science and Mathematics lecturers were exposed to the teaching methods of Science and Mathematics. The major thrust was on how to integrate Science and Mathematics using methods of integration and thematic teaching. This was funded by UNESCO. This was a workshop worth attending considering the wealth of experience that participants were exposed to in teaching Science and Mathematics in an integrated manner.*

CBL Humba had this to say.

> *It was sad to realize that some of the teacher educators do not attend the workshops even if the workshops were made compulsory. Such workshops become irrelevant to those teacher educators who did not attend. The teacher educators did not benefit from the workshops. Most of the teacher educators who attended the workshops could not comprehend the content and failed to learn and put the knowledge into practice. Also attending this workshop was a mind-spinning venture for both the teacher educators and the workshop organizers. Teacher educators who would attend such workshops wanted to benefit from money they would acquire at the end of the workshop. Regrettably, there was no form of assessment of the content and methodologies used by the facilitators during the workshop. Teacher educators did not input into the content that they were supposed to learn as a result, the content was divorced from the needs of the teacher educators. This compromised the effectiveness and efficiency of the workshops.*

The message coming out of these participants was that workshops for professional development were held in information and communication technology, Mathematics and Science. Teacher educators were trained in teaching methods of Science and Mathematics. The integrated approach was the major thrust. The Computer Science teacher educators benefited from the Masvingo ICT in Africa where they were exposed to the digital world. However, teacher educators felt that the workshops were not made compulsory. Such workshops became irrelevant to those teacher educators who did not attend.

Most of the teacher educators who attended the workshops could not comprehend the content especially the ICT one. Teacher educators did not input into the content that they were supposed to learn as a result the ICT workshop content was divorced from the needs of the teacher educators.

4.7.8 Provision of Support by Government

The government is the major stakeholder in higher education. Most of the teacher education colleges in Zimbabwe were owned by the government. The government as a major stakeholder in teacher education should take lead in providing support to institutions of higher learning the government could appeal to various partners around the globe for assistance. Respondents were teacher educators and directors from head office. They were asked to judge whether the government provided support to teacher education colleges. They all acknowledged that government provided support to teacher education colleges, the results were as shown in Figure 4.19.

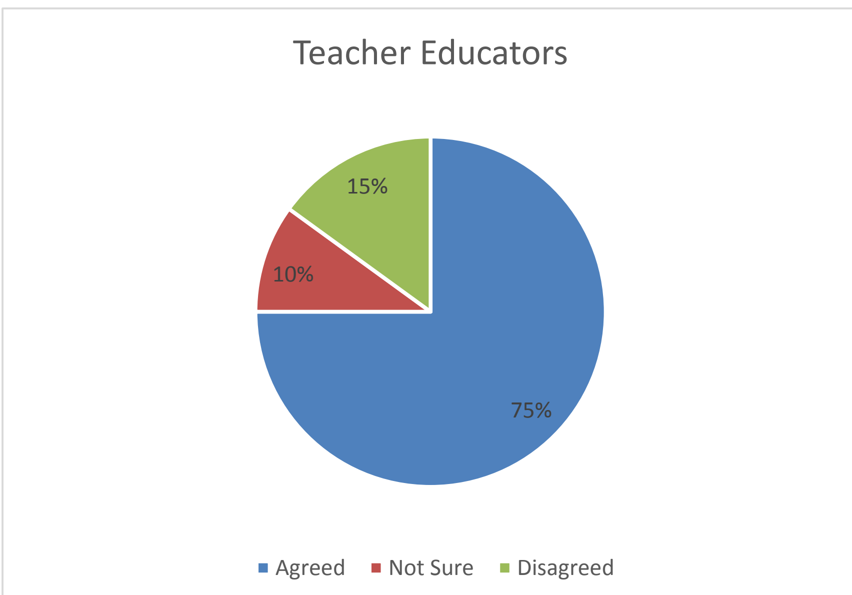

Figure 4. 19 Provision of support by government

The pie chart indicates that most of the teacher educators 75% (n=15) agreed, while 15% (n=3) disagreed, 10% (n=2) were not sure of the government support. The teacher educators overwhelmingly agreed that government supported teacher education institutions. The following were qualitative narratives from participants indicating government's support to teacher education colleges.

DHOI1 commented:

> *The government of Zimbabwe has disbursed US$5 million for the training of Science teachers as the country moves to alleviate shortages of STEM teachers. Since the inception of the STEM projects, government has availed US$5 million to three teachers' colleges, namely, Mkoba, Joshua Mqabuko and Masvingo for the programme. By the end of the year the government will also avail USD$2 million for further development of college science teacher training in teachers' colleges. In terms of Information, Communication Technology Infrastructure, the Ministry's target was to have free Wi-Fi for students in all 13 state universities and colleges by August 30 this year (2019). Furthermore, we have also received US$6 million for industrial parks and innovation hubs with the construction of infrastructure at advanced stages in most universities.*

DHOI2 concurred:

> *The Government is the primary sponsor of Education in Zimbabwe. All state-run educational institutions' students pay tuition and boarding fees while the duty of the building infrastructure and salaries for lecturing staff lies with the Government. In cases where educational institutions are owned by local authorities or by mission schools, the government takes the responsibilities of paying salaries for lecturers*.

DHOI1 opined:

> *The Zimbabwean Manpower Development Fund (ZIMDEF) is a fund established in terms of the Manpower Planning and Development Act (Chapter 28:02). Its purpose is to finance the development of critical and highly skilled manpower through a percentage training levy paid by registered companies in Zimbabwe.*

This fund is also available for training STEM teachers in teachers' colleges in Zimbabwe.

DHOI2 indicated:

As a government, we are saying that those subjects (STEM) that drive the economy and shape of the future of a student must be compulsory. Furthermore, the government launched the Capacity Development Programme, and as l speak about it here it is underway and l am stoking it with an additional 2500 teachers by the end of the year so that we have 5000 teachers studying those disciplines (STEM).

Furthermore, DHOI1 commented:

Under the new curriculum thrust, the government is working on retention allowances for the Mathematics, Science and Technical Vocational Lecturers in colleges and secondary schools.

In an interface with teacher educators, they concurred that the objective of training STEM was to increase the supply of teacher educators and Science and Mathematics teachers. In discussion with teacher educators there were only three teachers' colleges that were mandated by the government to train STEM teachers through ZIMDEF and capacity development programmes. The number of STEM teachers from these programmers was a drop in the ocean.

In an interface with student teachers, they indicated that government increased Wi-Fi connectivity in teacher education colleges. This was a noble idea. Student teachers indicated that there were frequent power outages in the country that affected Wi-Fi connectivity. Furthermore, student teachers had no laptops and as such that did not help very much. Student teachers from College B (CB) indicated that the college generators were available for a short period because diesel was expensive and not available in the country.

In discussion with teacher educators, they indicated that government was assisting teacher education colleges through the construction of infrastructure. Teacher educators indicated that college infrastructure was a thorn in the flesh. Lectures were being conducted in the library as the available space was limited due to large enrolments in teachers' colleges. During lectures, there were overflows of student teachers due to limited infrastructure. Some of the lecture rooms were being converted into laboratories. This reduced the number of infrastructure available in teacher education colleges. At CB, there were no lecture theatres, a basic requirement for an institution of higher learning.
Teacher educators further indicated that government paid retention allowance for STEM educators at some time but abruptly stopped the payment. However, retention allowance in an inflationary environment would help very much. They further indicated that related to retention allowance was payment of salaries to STEM teacher educators. Teacher educators bemoaned that salaries were being constantly eroded by inflation daily if not hourly.

The emerging issues from the participants were that the government as a major stakeholder in teacher education supported teachers' colleges through training STEM teachers, providing free Wi-Fi, infrastructure construction, payment of salaries and retention allowances for the STEM teacher educators, established the new technology and innovation policy. These forms of assistance were meant to ensure that STEM Education was successfully implemented in the country.

However, teacher educators felt that the assistance was not adequate considering that infrastructure was a thorn in the flesh for most of the teacher education colleges. Lecture rooms were being converted into laboratories; libraries were being turned into lecture rooms. There were overflow of students during lecture time and finally in some teacher education colleges there were no lecture theatres. It was therefore prudent to deduce that government as a major stakeholder in teacher education colleges rendered support in the form of infrastructure, salaries and policy guidance.

4.7.9 Provision of Support by Non-Governmental Organisations (NGOs)

Non-Governmental Organisations are institutions that partner with government in aiding in areas they deem fit. Non-Governmental Organisations are an example of external support to STEM Education curriculum implementation. The respondents, both teacher educators and student teachers, were afforded the opportunity to state different stakeholders supporting teacher education colleges in STEM Education in particular. The respondents concurred that various NGOs were aiding teachers' colleges.

4.7.10 Provision of Support by Non-Governmental Organisations

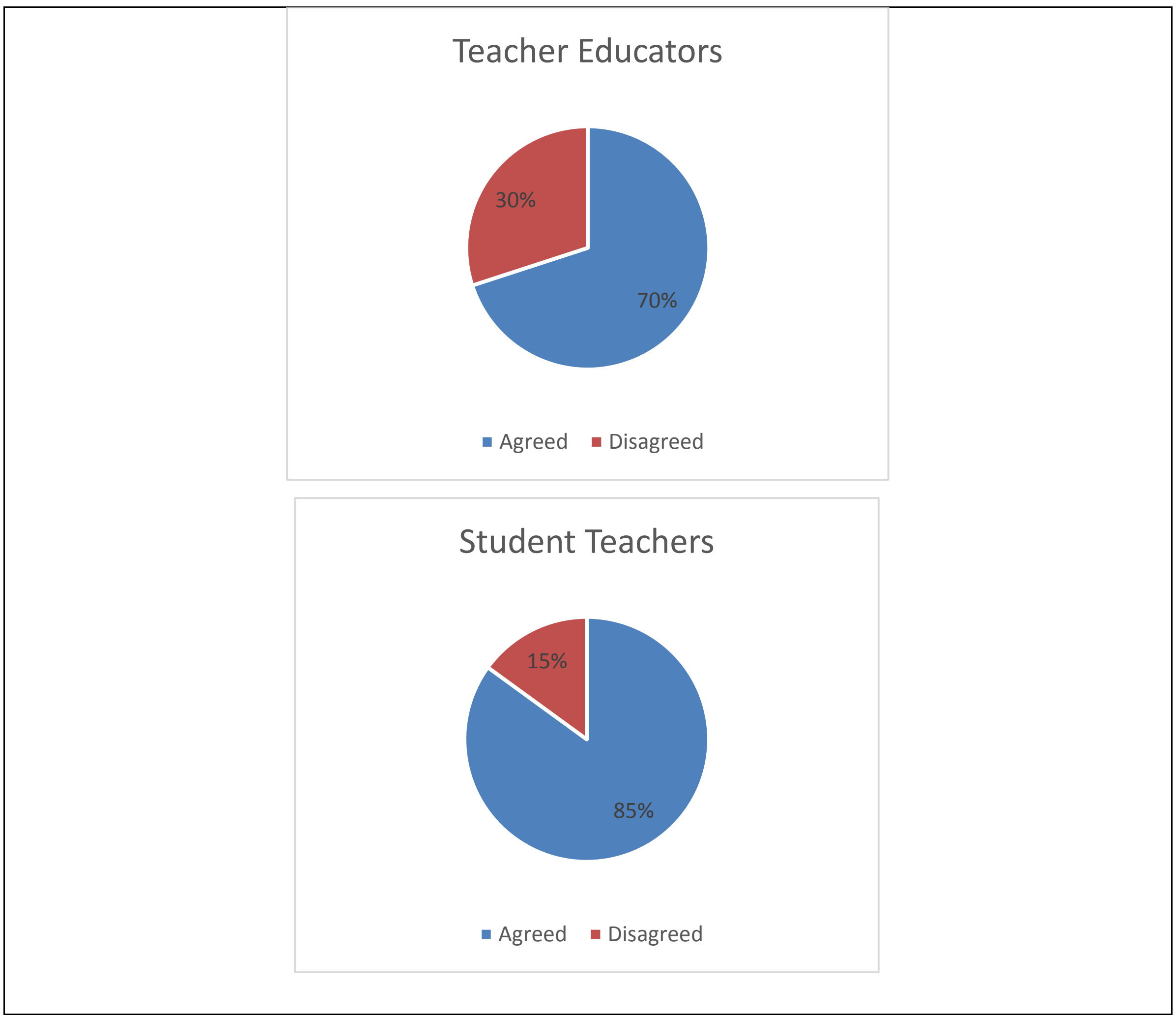

Figure 4. 20 Provision of Support by Non-Governmental Organisations

The above pie charts (Figure 4.20) indicate that most of the teacher educators 70% agreed whereas 30% disagreed. The student teachers, 85% concurred with teacher educators. The emerging trend was that NGOs supported teacher education colleges in STEM Education. The following were narratives indicating various non-governmental organisations that support teacher education colleges.

DHOI1 said:

> *The Ministry is also getting support from UNESCO and Korea. The Ministry is investing US$10 million as educational loan. The money has been deposited with banks and it is expected to increase to US$20 million by year end. We also have commissioned 40 state of the art desktops and 16 spots-throw projectors. These are being used for research, learning and teaching of STEM Education*.

DHOI2 alluded:

> *There are several NGOS that support STEM Education in Zimbabwe. Japan International Cooperation Agency (JICA) has projects to strengthen Mathematics and Science in tertiary institutions in Zimbabwe. JICA uses the Japanese lesson/study model which requires teachers to work on face to face teams to discuss and improve their practice. This has had valuable success which appears to be partly dependent on the teacher's willingness to commit to the program. There are programmes that are prescribed to certain teachers' colleges in Zimbabwe. Such programmes have been extended to the teaching of Physical Education and all Arts (mass display initiatives).*

CBL Humba alluded:

> *Japanese government through JICA supported the training of STEM teacher educators and student teachers in teacher education colleges. This was a noble idea. The only challenge was the way teacher educators and student teachers were selected for the programme.*

CASTI acknowledged:

> *We were told by the college principal that was going to be training STEM Educators, sponsored by JICA that there was going to be selection of teacher educators and student teachers for the programme. The selection procedure was not explained to us. We eventually heard that teacher educators and some student teachers had already attended the training.*

Participants agreed that non-governmental organisations were supporting STEM Education in teacher education colleges through loans from Korea and capacity development workshops by JICA. JICA strengthened the teaching of Mathematics and Science in tertiary education institutions. This was meant to reduce the shortage of teachers in STEM Education in teacher education colleges.

The JICA programme was a noble idea according to teacher educators and student teachers. However, they felt they were not happy with the criteria used to select both teacher educators and student teachers who were to participate in the training programmes. The teacher educators and student teachers felt it was not explicit. There was a lot of bias on who was to participate. The programme was not for every STEM teacher and student teacher. It was prudent to deduce that non-governmental organisations supported STEM Education implementation in teacher education colleges.

4.7.11 Provision for Support by the Department of Teacher Education

The University of Zimbabwe Department of Teacher Education (UZ DTE) had an associate ship with all teachers' colleges in Zimbabwe. The DTE under the Faculty of Education was responsible for assessment, evaluation and monitoring of teacher education activities. The respondents were teacher educators, student teachers and directors in the ministry. They all concurred that the DTE provided support in terms of professional development, assessment and evaluation to both teacher educators and student teachers. Figure 32 shows data gathered:

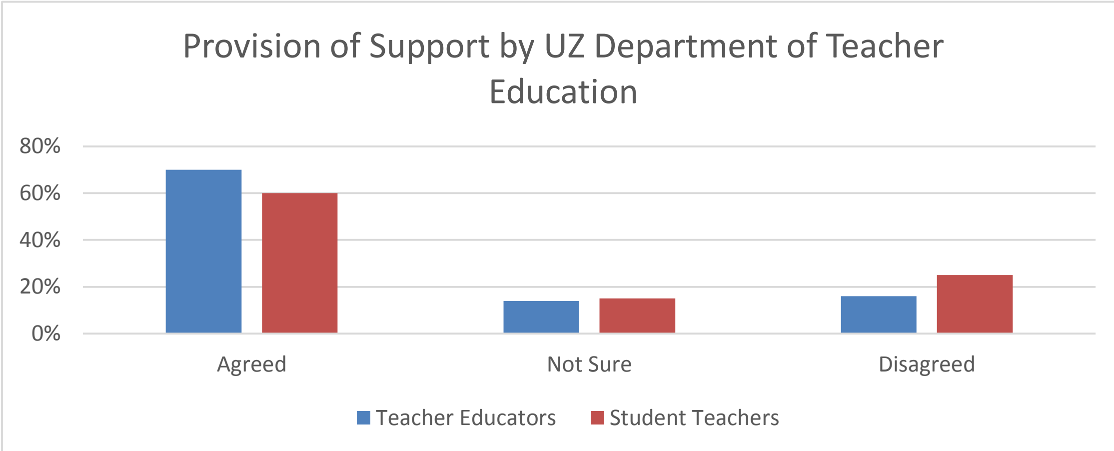

Figure 4. 21 Provision of Support by UZ Department of Teacher Education

As shown in Figure 4.21, most teacher educators 70% and student teachers 60% agreed that there was support. 16% of the teacher educators and 25% of the student teachers, however, disagreed. About, 14% and 15% of teacher educators and student teachers, respectively, were not sure. There was convergence between teacher educators and student teachers in that teachers' colleges were supported by the UZ Department of Teacher Education. In addition, the following were qualitative responses from participants:

CALIHSM opined:

> *There is a lot of support from the associated University of Zimbabwe's Department of Teacher Education (DTE). DTE assists teachers' colleges through curriculum development. Teachers' colleges develop their own syllabuses and DTE approves the these for implementation. This process assures quality control and assurance in teachers' colleges. DTE also allows colleges to set examinations in STEM subjects. After setting the examinations, DTE standardizes the examinations. The Department of Teacher Education is the custodian of the examinations before they are written by students in colleges. The role of DTE here is to assist in moderation of examinations in colleges.*

CALFGD concurred:

The University of Zimbabwe supports teachers' colleges with continuous professional development workshops. The department identifies the facilitators and training materials for the workshops. Recently a workshop was held in Marondera where college lecturers went through rigorous activities in research and development, curriculum implementation and development in STEM.

UL2 acknowledged:

There are a growing number of institutions that are partnering with teachers' colleges to support STEM Education. The University of Zimbabwe Department of Teacher Education has been working to integrate STEM into the primary school curriculum. DTE believes that Engineering motivates students learning of the Mathematics and Science concepts that make technological development possible. Professors and staff members assist lecturers in teachers' colleges through workshops and train teachers on the need to be technologically resourceful.

The above perceptions were further substantiated in an interview with one of the teacher educators.

CALI Hwangwa acknowledged:

The DTE through the programme of associate ship was supporting teacher education colleges through quality assurance. The DTE lecturers would make interim visits to teacher education colleges. The DTE also does academic examining and certification of student teachers who would have successfully completed the Diploma in Education programme.

CBLI Mahingi lamented:

Some of the DTE external assessors during academic examinations appear arrogant. They do not allow exchange of ideas and academic autonomy. They tend to prescribe solutions to colleges. At the end of the day, colleges do not seem to embrace such external assessors.

It was prudent to deduce that the University of Zimbabwe, Faculty of Education through the Department of Teacher Education rendered support to teacher education colleges. The support was in the form of professional development workshops in research, curriculum development, design, implementation and training of teacher educators in Science, Technology Mathematics and Engineering. Under the scheme of associate ship, the DTE supported teacher education colleges through quality assurance, interim visits, student teachers' supervision, academic examining and certification of student teachers who would have successfully completed the Diploma in Primary Education.

4.8 Why Teachers' colleges Face Challenges

This forms the fourth sub-research question of this study.

Respondents were teacher educators, student teachers, university lecturers, and education directors.

4.8.1 Inadequate Funding

Funding of STEM Education is central to successful implementation of the innovation. Most of the countries that successfully implemented STEM Education were adequately funded by different stakeholders. The following are narratives from different participants regarding funding of STEM Education in teacher education colleges.

In an interface with CALFGD, lecturers acknowledged:

> *There is inadequate funding for the programme at teachers' colleges. There is lack of campaign for the programme at teachers' colleges and there is lack of campaign education on STEM subjects. Teachers' colleges do not have adequate resources for STEM Education.*

Furthermore, student teachers concurred:

> *At our college there are inadequate funds to provide better facilities for STEM subjects.*

CBL Gonyeti concurred:

> *Teachers' colleges lack financial support from the government. The financial support from government is inadequate to cover all the expenses teacher education colleges need for STEM Education. There are many teacher education colleges in Zimbabwe that are looking for government support in terms of finance. The government is not able to finance all such colleges.*

CBL Humba acknowledged:

> *The colleges were funding themselves from projects such as academic tuition for Mathematics and Science for O and A-Level. These projects provided funds to teacher education colleges. These funds were inadequate to cover all general expenses for the colleges.*

CBL Kudakwashe Rombe commented:

> *The tuition fees paid by student teachers were inadequate to cover for the general expenses of the college. Student teachers, some of them are failing to pay tuition fees for their academic semesters. As such the colleges are always in debt because student teachers cannot afford to pay the fees.*

Teacher educators bemoaned that some of the funds that were directed to colleges were not specifically for STEM. They were meant to cover the general operational costs for the colleges. Also, government as the responsible authority was not adequately funding the state colleges. Colleges, relatively, funded themselves from tuition fees paid by student teachers and fundraising projects carried out in the respective teachers' colleges.

4.8.2 Lack of innovation by College Leadership

The following were narratives regarding college leadership in STEM Education.

One of the teacher educators CBLI Kudakwashe Rombe commented:

> *Most of the leadership in teachers' colleges lack much needed innovative competencies and do not readily accept change. They resist change. Additionally,*

the leadership in the primary teachers' colleges does not have background in primary school education, having been trained as secondary school teachers themselves. This has a negative impact on how they lead these institutions of higher learning.

Furthermore, in an interface with teacher educators. CBLFGD, they alluded:

Poor leadership in education institutions, unfortunately have led to the status quo. Leadership unfortunately has little incentive to produce more or better STEM graduates, especially graduates with the kind of skills needed by industry. It is not a failure of imagination or knowledge but failure of will on the part of the college leadership.

In the same vein CALI Hwangwa lamented.

There is ignorance on the STEM Education system by the college executive management. The college authorities do not have answers on how STEM is implemented. The college management resists change brought by introducing STEM Education at college level.

4.8.3 Shortage of STEM Teacher Educators

STEM teacher educators played a pivotal role in ensuring the strategies used to implement STEM Education in teacher education colleges. The following were narratives regarding the availability of STEM teacher educators in colleges.

CBLFGD alluded that:

Some colleges do not have Science lecturers, which is not a good thing. As a result, a lot of student teachers are found lacking in scientific knowledge and skills.

ULI2 lamented,

There are inadequate science lecturers; the teaching of STEM is thus affected by the lack of experienced, knowledgeable and skilled teacher educators in teacher education colleges.

Furthermore, in an interface with DHO1:

> *In Zimbabwe there is a serious shortage of approximately 1 526 Science and Mathematics teachers as of November 2019. This shortage is due to demand of such teachers in say South Africa, Namibia, Botswana, Australia and United Arab Emirates. Such teachers tend to land on lucrative deals; regionally or globally, therefore, they remain reluctant to return to Zimbabwe.*

DHOI2 acknowledged:

> *As a Ministry, attracting lecturers to teach in STEM subjects is problematic for many reasons. First, there is a shortage of young people with STEM knowledge. Second, for those young people with relevant knowledge and qualifications, teaching is not seen as an attractive profession.*

CBL Takawira commented,

> *In the Physics Department, there are currently two lecturers instead of an establishment of six lecturers. The lecturers resigned from the Ministry at the end of last year (2018). We have advertised to fill up the vacant posts, but we are failing to get suitable candidates for the post. The department is currently understaffed.*

CBL Duncan said,

> *We are understaffed as a department. There are three lecturers in posts currently. We are supposed to be six lecturers. The other three did not return after the December school break. The posts have been advertised several times, but the college is failing to get the right candidates. We are currently overloaded with work as there are more students on campus now.*

CAL Mashavave commented,

There are several vacant posts in our department. We are understaffed. We are supposed to be six in post. As of now we are only two. The college has advertised for more lecturers, but we are failing to have the most suitable candidates to fill in the vacant posts.

CALHSM had this to say,

The Mathematics Department is currently understaffed. We need two more lecturers to fill up the vacant post. We are overwhelmed by the student teachers. As a department we have advertised several times, but we are failing to get the most suitable candidates to fill in the vacant posts. We hope one day we will get the most suitable candidates.

4.8.4 Limited STEM Knowledge by Teacher Educators

Teacher educators' knowledge is critical especially in Engineering as one discipline for STEM. The following were narratives regarding STEM teacher educators' knowledge in Engineering.

In an interface with CALIHSM, he had this to say:

Teacher educators lack knowledge of STEM. The STEM initiative was introduced without considering human capital development.

Furthermore, ULI2 lamented:

Science teachers are poorly equipped to teach Engineering. Few science teachers have had even one Engineering course. The faculty members who prepare future teachers have limited experience with Engineering education. Thus, the current generation of teachers has not been prepared to incorporate Engineering into science teaching and even if science teachers had appropriate preparation. There is insufficient time to do justice to science topics. I am convinced that many have not had any industrial work-related experience. It is difficult to expect a science teacher educator in this situation to be able to effectively model and explain the *work of an Engineer s/he does not understand it or have not done it herself or himself.*

4.5.5 Poor Remuneration of Teacher Educators

It emerged that teacher educators agreed to the fact that poor remuneration was among the overarching push and pull factor in tertiary institutions.

In an interview with CALI Shangwa:

> *The erosion of a Zimbabwean teacher's salary from around US$500.00 per month to the current, under US$30.00, relegated teachers to extreme poverty and subsequently compromise their capacity to deliver quality service. It is a shame.*

Furthermore, an interface with CBLI Nyoni indicated that:

> *Poor remuneration in teacher education colleges has led to moonlighting by teacher educators. A sizeable number are doing part time in universities and private colleges around the country. Such teacher educators are conducting these lectures during the weekdays, thus compromising their attendance to the college student teachers. Teacher educators are disengaged and unenthusiastic.*

In unison, DHOI1 indicated,

> *One of the being challenges being faced by teachers' colleges in Zimbabwe was poor lecturer remuneration. Pathetic salaries tend to demotivate the lecturers and it is also one of the push factors fueling brain drain in the country.*

4.8.6 Lack of STEM Background by Student Teachers

Teacher educators acknowledged that student teachers lacked the requisite background knowledge in STEM subjects or education through the following narratives.

CBLI Kudakwashe Rombe commented:

> *The pre-service teacher trainees are not mathematically competent. They had several sittings in Mathematics before they passed the subject at Ordinary Level. Also, at Ordinary Level, they would have been exposed to Integrated Science,*

which is not demanding, compared to natural sciences, namely: Physics, Chemistry, and Biology.

Furthermore, singing from the same hymn book. CBLI Prof Logic concurred:

That pre-service teacher trainees in most teachers' colleges in Zimbabwe lack basic science knowledge because of the curriculum they have been exposed to at Ordinary Level.

Also, CALFGD indicated that:

The majority of the pre-service teacher trainees do not have the required background for STEM Education. Most of the pre-service student teachers did Integrated Science at Ordinary Level. It was not challenging at all.

One of the pre-service student teacher CASTI concurred:

At Ordinary Level l did not do natural sciences. I am failing to fill the gap that exists between the two. It puts me under a lot of pressure.

CALI Nyamuscom posited:

The STEM fluid is new to pre-service teacher trainees and they found most of the work new to them. The trainees lack basic scientific knowledge which is needed for implementing STEM Education.

4.8.7 Lack of Focus by the Government

It was prudent to assess the ideological focus of STEM. Respondents confirmed that government lacked focus on STEM Education through the following narratives.

In an interface with ULI1:

The major problem in Zimbabwe is lack of focus. Currently, there is much noise about STEM Education but come two years down the line, this will be history. No one will be talking about this.

Reading from the same page, CBLI Gonyeti, concurred:

The programme has come in as a political ideology without prior analysis of what should be followed to enable its full implementation.

Furthermore, ULI3 lamented:

There is lack of clarity on the basics and rationale for STEM. This has never been made public and neither have we seen it in different official languages of Zimbabwe.

4.8.8 Limited Infrastructure

Infrastructure was a thorny issue in teacher education colleges. Earlier on in some part of this study infrastructure was examined. Respondents agreed that there was limited infrastructure in teacher education colleges.

In an interview with DHOI, he had this to say:

The causes of challenges are wide reaching and interrelated, including poor resources and infrastructure.

Furthermore, CBFGD acknowledged:

Infrastructure deficits, resource inadequacy and high teacher/learner ratio are some of the root causes of challenges.

In concurrence, CBL Prof Logic had this to say:

In teacher's colleges there are too many students for professional studies syllabus B. It is not possible to carry out experiments with large groups of pre-service student teachers. Lectures for Professional Studies Syllabus B combine the whole intake of about o 300 student teachers into the lecture theatre.

Having looked at why teacher's college face challenges, the next issue focuses on the summary of the chapter.

4.9 Summary

This chapter presented and analyzed the data collected through the questionnaires, interaction, focus group discussions and documents. The main objective of the study was to interrogate implementation of strategies used by teachers' colleges to prepare pre-service teachers for Science, Technology, Engineering and Mathematics in Zimbabwe. Data were collected from lecturers from primary teacher training colleges, final year pre-service teacher trainees, the associated university's Department of Teacher Education Lecturers and Ministry of Higher and Tertiary Education, Science and Technology Development. Data were categorized into four basic themes, which are, knowledge of STEM Education; which individual competencies and skills of lecturers, teaching strategies (methodology) which were being used to implement STEM Education, resource materials and equipment; support systems that were in place for teachers' colleges and why the colleges faced challenges when implementing STEM Education in Zimbabwe. The next chapter discusses the findings of the study.

CHAPTER 5

DISCUSSION OF FINDINGS

5.0 Introduction

The previous chapter presented and analysed the findings from this study. This chapter discusses the findings around the themes developed from sub-research questions. These include knowledge of STEM Competencies and skills of teacher educators, delivery methodologies used to prepare student teachers, resources, facilities and support systems available in teacher education colleges and why teachers' colleges face challenges in preparing pre-service teachers for STEM Education.

5.1 Knowledge of STEM Education

5.1.1 Competence of the College Lecturers

It was seen prudent for this study to seek the respondents' understanding of STEM Education as it was key to this study. The understanding of STEM would reflect how various respondents would assess issues being interrogated in the study. It was also meant to establish whether the teacher educators, student teachers, university lecturers and directors shared a common understanding of STEM Education. Findings from the study revealed a shared understanding of STEM Education. STEM Education was perceived as a popular acronym, characterized by interdisciplinary, fused, trans disciplinary, integration, and thematic incorporating all the four STEM disciplines to allow students to develop real world skills and competencies. This was in line with White's (2014) definition which referred to STEM Education as an acronym which stands for Science, Technology, Engineering and Mathematics. Australian Council for Education Research (2016) defined STEM as a term used to refer collectively to the teaching of the disciplines within its umbrella, Science, Technology, Engineering and Mathematics. Basham and Marino (2013) in Ntemngwa and Oliver (2018) described STEM as representation of educative efforts that exploit a symbiotic relationship among the four interwoven fields. This definition of STEM stressed the interdependence of the four disciplines. Tyson, Lee, Birman and Harrison (2003) in Gonyea (2016), define STEM as conglomeration of the four disciplines, and the four subjects together are actively involved in providing many of our modern conveniences. Tsupros (2008) defines STEM as an interdisciplinary approach to learning where rigorous academic concepts are coupled with real world lessons as students apply Science, Technology, Engineering and Mathematics in contexts that make occupations. It was inferred that although characterized by variations in definitions STEM Education was viewed in the same way by both respondents and participants of this study. This was viewed as important as all participants had conceptual understanding of STEM. It was significant because it served as a basis for understanding issues considered under this study.

5.1.2 Teacher Educator's Professional Competencies

Rogan and Grayson (2003) curriculum implementation framework (CIF) acknowledge that the teacher factor is one of the most important enablers of curriculum implementation. This implies that teacher educator's knowledge is key towards STEM implementation in teacher education colleges. Molapo and Pillay (2018) acknowledged that teacher factor, under capacity to innovate refers to teacher's ability to teach depending on qualifications, experience, professional development as well as teacher's knowledge and the pedagogical content knowledge. The study established that teacher educators had the professional qualifications, experience, content knowledge and pedagogical content knowledge for STEM Education in Zimbabwe because of training and experience. This finding is coherent with Magnusson et al (1999) , Magnusson has the following forms of knowledge, orientation to teaching science which refers to teacher's knowledge and beliefs about Science and Mathematics, knowledge and beliefs about Science curriculum, knowledge of students understanding of Science, knowledge of assessment in science, knowledge of specific strategies of teaching Science and knowledge of topic specific strategies. Furthermore, Lee and Luld (2008) assert that subject matter knowledge, knowledge of the goals, student teaching, curriculum organisation, assessment were resources necessary in teaching. Since these forms of knowledge are important when it comes to who should be teaching STEM and not. These forms of knowledge are important to the teaching of STEM in teacher education colleges. It was evident that the participants in the study had forms of knowledge that enabled them to teach STEM education in primary teacher education colleges in Zimbabwe.

Furthermore, the teacher educators were mature with a lot of experience. This finding concurs with Kyere (2017) who revealed that students needed to be coached by well experienced teachers who will be abreast with handling hands on material to effectively teach STEM subjects. The researcher was of the feeling that in addition to subject matter knowledge, pedagogical content knowledge, experience and qualifications. STEM teacher educators should have technological pedagogical content knowledge. A holistic STEM primary teacher educator should have technological pedagogical content knowledge in addition to other forms of knowledge.

It emerged from the findings that one teacher educator was under qualified to teach STEM Education. In contrast, Goldhaber and Brewer (1998) found that earning a subject specific degree had a positive effect in student achievement in both Mathematics and Science. Additionally, Nwanekezi et al (2010) assert that STEM teacher educators as facilitators should not only be knowledgeable in the subject but should also possess the basic and necessary skills with which to develop the knowledge of the subject. A study by Kyere (2016) revealed that students needed to be mentored by well experienced teachers who are abreast with handling hands on materials to effectively teach STEM subjects. This researcher considered that an under qualified teacher educator hag very limited knowledge and insight in teaching Computer Science. Deliberate efforts in professional capacity development and upgrading one's professional qualifications through enrolling in degree programmes befitting one's tour of duty might assist the teacher educator and the college at large.

5.1.3 Incorporating STEM Education in the Curriculum

The competence and skills of selecting subject content, and pedagogical content knowledge are measured through designing STEM syllabus, teaching programmes and course outlines of repute. All these encompass knowledge of the curriculum. The study revealed that the teacher educators had knowledge of the STEM curriculum. This finding dovetailed with Magnusson et al (1999) second component of PCK which is about the knowledge and beliefs about Science curriculum. Curriculum is conceived as knowledge of goals and objectives in subjects the students are teaching, besides the expression of these guidelines through day topics addressed during an academic year. Schulman (1987) confirms Magnusson et al (1999) knowledge of the curriculum by stressing that one of the forms of teacher's knowledge is that of curriculum. Magnusson et al (1999) are more elaborate and specific on knowledge of the curriculum that it involves the ability of the teacher educators to formulate goals and objectives for the subject content to be taught in a specific period. The respondents of the study were well grounded in knowledge of STEM curriculum in primary teacher education. As such, graduates were also well grounded in the knowledge of the curriculum, which is considered important for teaching STEM education at primary level. This researcher considered knowledge of the curriculum critical in understanding STEM Education. Knowledge of the curriculum should be deliberately introduced in teacher education colleges as a course, such that, the graduates are well grounded in different forms of knowledge that are considered important in teaching.

5.1.4 The Utility of STEM Education

The utility of STEM Education incorporates its value, use and purpose to student teachers and the nation. The study established that the participants were aware of the use, value and purpose of STEM Education. STEM Education promotes skills development in student teachers. This finding resonates with White (2014) who asserts that STEM Education was meant to provide all students with critical skills, problem solving skills and creative skills that would enable them to solve problems in the now and future. These skills ensure that student teachers are well prepared for the 21st Century STEM Education. The student teachers would cascade the 21st Century skills to their learners in various primary schools in the country. The major thrust of STEM Education is thus skills development. The skills, ordinarily, would be used in various economic sectors.

It also emerged that STEM Education was for employment creation. This finding was in line with the National Academy of Science Committee on Science Engineering and Public Policy (2007) assertion that in United States of America, many attempts were introduced to produce and increase available workers in STEM fields, in government, industry, leaders and educators. The National Academy's assertion indicates that STEM Education is for employment purposes. Additionally, the National Science Foundation acknowledges that 5 million people are employed in fields such as Science, Engineering and Technology which makes up about 4% of the total workforce. This is a significant figure of workers employed in STEM related fields of the economy in America. Therefore, the purpose of STEM Education was seen to be centered on job creation, particularly in the wake or soaring unemployment statistics. The participants revealed that STEM Education was for technological development too. Technological development was crucial for economic growth and productivity. This finding was congruent with Gonyea (2017) assertion that STEM Education was critical to the economic growth and productivity of the country. Technology increases industrial output, thus increasing productivity of the country. If productivity increases, economic growth also tends to increase.

It emerged from the study that STEM Education's purpose was industrialization of the nation. Industrialization is growth of industry through STEM related fields such as Science, Engineering and Technology. As such, STEM Education increases the number of industries through encouraging learners to take up STEM subjects. This is seemingly in line with Obama's (2009) administration crusade to inspire and encourage students to excel in STEM disciplines. If more students enrolled for STEM Education disciplines, it was assumed that this translated to the establishment of more STEM related industries in the country. Ultimately, the increase meant increase too in the number of industries, productivity and economic growth.

5.2 STEM Teaching and Learning Appr0aches

5.2.1 Teaching Methodologies Used by Teacher Educators

The delivery methodologies formed the second sub-research question of this study. The respondents mentioned numerous STEM teaching methods they used to teach student teachers in colleges of education. Respondents identified inquiry-based methods. This finding was congruent to Dogni and Kalender's (2007) study which found out that learners who had learnt through constructivist methods indicated better knowledge retention than did the learners who had learnt the same subject matter through conventional methods.

Additionally, Geiers (2007) study also found out that inquiry-based teaching methods reduced the achievement gap by African American learners. Also, Chee and Adhaw (2008) acknowledge inquiry-based teaching methods, emphasises skills and attitudes, higher order thinking skills, creative problem solving, design and construction of the object. Furthermore, inquiry-based methods are STEM specific. This augurs with Magnusson et al (1999) under knowledge of subject specific strategies which includes general approaches utilised during performing the science instruction such as guided inquiry.

Furthermore, inquiry-based methods are hands on pedagogy. Kyere (2017) revealed that hands on pedagogy have the potential to make students active learners, promote a high level of participation and motivation. The researcher shares Kyere's (2017) contention that hands on promotes not only higher levels of participations but also self-efficacy within the learners.

It emerged from the study that teacher educators employed problem solving or problem-based learning to teach STEM Education in teacher education colleges. Problem based learning encourages learners to be active and experience learning. This finding is coherent with Mohtar (2016) assertion that problem-based learning is a teaching strategy that encourages student teachers to be active learners by engaging them in problems that need various solutions. To get solutions, the student teacher must interpret the problem, gather information, identify possible solutions, and evaluate possibilities and present solutions (Ahmed, 2008). The process encourages learners to think critically and creatively when they encounter problems in future (Mohtar, 2016). Problem based learning promotes creativity and critical thinking in learners.

The study revealed that outdoor or field trips were employed to teach student teachers in STEM Education. Field trips provide hands on experience. This finding is congruent to Goulder (2012) assertion that outdoor learning provides the firsthand experience of biodiversity and ecology to the learners particularly studying Biology/Life Science and Geography. Furthermore, John and William's (2017) study revealed that learners perceive field trip learning to be enjoyable and worthwhile experience as it allows them to collect real data from the environment. Also, field trips help learners to feel more involved in their learning disciplines (John and William, 2017). Field trips are hands on, inquiry based and constructivist in nature.

The study also established that discovery learning was one of the teaching methods employed by teacher educators to teach STEM Education. The method allows student teachers to get firsthand experience. This finding concurs with Jummai's (2011) assertion that this approach enables learners to get firsthand experience in facts, concepts, principles and processes. Discovery learning aids learner's memory (Atadoya and Onaolapo, 2008). In discovery method, the main idea of teaching is concept formation (Jummai, 2011).

It emerged from the study that teacher educators used cooperative learning to teach student teachers STEM disciplines. Cooperative learning enhances active involvement of the learners. This finding, dovetails with Strivers (2010) assertion that cooperative learning encourages active engagement by the learners and builds critical skills needed in today's workplace. Furthermore, cooperative learning allows students to collaborate with others from different places and cultures (Strivers, 2010). This cooperative learning encourages teamwork and team building.

The respondents revealed that project-based learning was one of the teaching methods used by teacher educators to teach STEM Education. Project based learning is content and skills-based teaching method. This finding is coherent with Strivers (2010) assertion that project-based learning teaches not just content but also important skills to the learners. The skills include communication, presentation, organisation, team management, research, inquiry, self-assessment and reflection, group participation, leadership and critical skills (Strivers, 2010). These skills are life-long. The aim of project-based learning is to produce a product.

Furthermore, the study revealed that experimental method was used to teach student teachers STEM Education. Experimental method allows learners to investigate. This finding is in line with Katukula (2018) assertion that learners investigate scientific problems, observe, gather, analyse and interpret data as they look for solutions to real life problems. Experimental methods allow learners to ask questions using theories and models to explain phenomenon and ideas evaluated against possible explanations and compared evidence (Katukula, 2018). In using experimental method, learners search for explanations by asking questions that lead them to an inquiry (Katukula, 2018). Experimental method is hands on, inquiry based and constructivist in nature.

The researcher concluded that teacher educators employed hands on and inquiry-based methods which were constructivist in nature. This is in line with constructivism theoretical framework which maintains that learning by doing improves knowledge retention. Such methods are obtaining globally where STEM Education has been introduced, for example, in Malaysia. The methods were 21st Century STEM Education pedagogy and inquiry based. The student teachers were equipped with an array of inquiry based methods suitable for teaching STEM education at primary level in Zimbabwe.

5.2.2 Variation of STEM Teaching Methods

Variation of STEM methods is the ability to distinguish between STEM specific methods, that is, considering subject demand and learner's ability and diversity. Respondents acknowledged that teacher educators were able to vary STEM Education methods. Such methods were STEM specific and addressing demand requirements of the subject. This finding concurs with Magnusson, et al, (1999) under knowledge of specific strategies that pedagogical content knowledge is also content specific o subject specific knowledge that is fundamental for effective science teaching. Subject specific entails strategies applicable to teach Science by teacher educators. Also, teaching methods differ with disciplines or subjects. As Abel (2008) acknowledges that pedagogical content knowledge differs from one discipline to another, for example, teaching Biology is different from teaching Chemistry. Therefore, teacher educators should vary teaching methods. Ejiwale (2013) asserts that STEM educators should endeavour to understand the available methods and teaching strategies and select them according to the demand of the lesson at hand with attention to the diverse nature of students in the classroom, their learning styles and abilities. Ejiwale (2013) considered the students learning styles and ability as important factors to consider for differentiating STEM teaching methods. There is more insight into Ejiwale's contention as learners are different in academic and learning style.

Teacher educators varied teaching methods to cater for individual differences among student teachers. Conversely, the teacher educator's knowledge of variation of STEM teaching methods differed considerably; student teachers and document analysis indicated that some teacher educators did not vary teaching methods in STEM. Such teacher educators lacked knowledge of instructional strategies, such as, subject specific strategies and topic specific strategies. According to Magnusson et al (1999), knowledge of specific strategies includes general approaches to teaching Science. Meanwhile, knowledge of topic specific strategies is employed to help student's comprehension in specific science concepts or principles; such knowledge includes the use of analogue models, illustrations and examples. Teacher educators could not vary STEM teaching methods according to disciplines and topics. They lacked knowledge of instructional specific strategies. Therefore, it was concluded that student teachers also lacked knowledge of instructional strategies for STEM. As if proffering a solution, deliberate efforts should be done to further capacitate teacher educators through workshops on capacity development programmes initiated by development partners and universities, such as, the University of Zimbabwe, National University of Science and Technology, and Harare Institute of Technology.

5.2.3 Adequacy of STEM Teaching Methods

Respondents indicated that STEM teaching methods were relatively adequate. Teacher educators employed a variety of STEM teaching methods to teach student teachers. Central and critical to the STEM Education methods identified by the respondents were problem-based learning methods, project-based learning and hands on. These teaching methods gave student teachers opportunities to solve real life problems. Problems could be solved through designing solutions through project and problem-solving methods. This finding concurs with Gaigher, Rogan and Brown (2006), Robabeh, Hassan and Farzad (2012), Sepeng, (2000), Sepeng and Web (2012) who acknowledge that problem- based learning is regarded as critical in the teaching and learning of STEM Education. Tambara (2015) acknowledges that problem-based learning is focused and experimental that is organized around the investigation explanation and resolution of meaningful problems. If problem-based learning methods were employed by teacher educators, then student teachers benefitted interacting with such critical STEM Education methods.

However, the researcher noted with concern, comments from a fraction of teacher educators and student teachers who categorically stated that STEM teaching methods were inadequate if laboratory method was not being used to teach student teachers. Laboratory Activity method is considered central, critical and integral to STEM teaching. According to Atadoya and Onaolapo (2008) laboratory activity enhances the students and sharpens their understanding in STEM. The researcher considers that laboratory activity method should be used in all STEM disciplines for effective STEM implementation. It can be safely concluded that student teachers at primary teachers colleges were not being exposed to laboratory activity methods in STEM disciplines especially Biology, Physics, Chemistry and Computer Science.

5.2.4 The Use of STEM Methodologies During Teaching Practice

It emerged from the study that student teachers applied the STEM teaching methods that they learnt at college. The student teachers were able to apply what they learnt from the capable peer (teacher educators). The researcher noted that there were elements of scaffolding by the more knowledgeable peers in which one could see the curriculum implementation framework by Rogan and Grayson's (2003) on Zone of Feasible Innovation being implemented. This also reflected that the student displayed the acquisition of knowledge from the experts to the novice that is from the teacher educator to student teacher. That is learning from more knowledgeable peers and applying it. Student teachers were able to acquire knowledge in terms of STEM teaching methods from the teacher educators and successfully applied the knowledge at various primary schools where they practiced. Having discussed STEM Education delivery methods, the subsequent section discusses findings on resources, facilities and support systems that were available in teacher education colleges to enhance STEM delivery.

5.3 STEM Resources, Facilities and Support Systems Available in Teachers' Colleges

The third sub-research question for the study sought to establish resources, facilities and support systems that were available in teacher education colleges to enhance the teaching of STEM Education in line with curriculum implementation framework (CIF) postulated by Rogan and Grayson (2003). This theme investigated the colleges' library resources, laboratory resource and support from government, non-governmental organisations and the UZ Department of Teacher Education.

5.3.1 Available Library Resources

It was established that the college library was well resourced with several e-journal houses, for example, EBSCO Host, sage, JOST, Francis Taylor and Emerald. There were many computers and a multimedia center in the library. The sound availability of library resources made it possible for student teachers to have access to current STEM journal articles and publications in their respective disciplines. The availability of college libraries ensured that student teachers had resources for STEM. This finding concurs with Ola's (2002) assertion that a well-equipped library is a major facility which enhances good learning and achievement of high educational standards. Popoola (2000) also acknowledged that colleges with well-equipped library resources normally maintain high academic performance.

It emerged from this study that part of one college's library was used as a lecture room for early childhood development. Such an observation was a cause for concern as student teachers ended up scrambling for limited space in the library. The student teachers research time was thus limited. There was a lot of interference and divided attention on the part of the student teachers. As such, the use of the library as a lecture room reduced the size and space available for student teachers. In contrast, Fuller (2008) found that the effect of library size and its activity have been positive. The reduced size and activities of the library at College B had negative effect on resources available for STEM Education in teacher education colleges. The researcher considers that more financial assistance should be availed in teacher education colleges for the construction of more lecture rooms for ECD, such that college libraries are reserved for student research in STEM Education. Financial resources can be availed through public private partnership with industry. Fundraising activities should be organized to raise more resources for the constructions of college infrastructure.

The study established the sound availability of ICT equipment, sport throw projectors, desktops, unlimited computers and unlimited Wi-Fi connectivity for student teachers and teacher educators. The use of ICT specific applications was an important resource for STEM teaching in colleges. This finding is congruent with Macfarlane and Sakellarion's (2002) assertion that using ICT either as a tool or as a substitute for the laboratory-based elements of an investigation can aid theoretical conceptual understanding in some topics in STEM Education. Furthermore, students in ICT supported STEM curriculum also benefit from instant feedback, experiences, independent and self-directed learning (Baggot La Velle et al 2003). Studies have shown that computer simulation can be used in teaching STEM subject concepts and improve scientific understanding across a variety of topics (Baxter and Preece, 2000, Huppert, Lomask and Lazarowith, 2002, Trindale, Fiolhais and Almedia, 2002, Zacharia, 2003). The research can infer that primary teacher education colleges had sound ICT equipment which eventually benefitted primary student teachers in STEM education.

5.3.2 Available Laboratory Resources

It is well accepted that laboratories serve as the nerve center for all STEM Education disciplines. The study sought to establish the availability and functionality of laboratories in teacher education colleges. The findings from respondents revealed that laboratories were available in teacher education colleges. In laboratories, student teachers carry out experiments, designed prototypes, and solved real life problems affecting communities. The laboratories are central to the teaching of STEM Education in teacher education colleges. The finding is coherent with Ogunyiyi's (2012) assertion that it is a place where theoretical work is practiced, students are involved activities, such as, observing, counting, measuring, experimenting, recording and carrying out fieldwork. Also, a laboratory is where learners are given the forum to exercise their beliefs, ideas, statements, and theoretical propositions, among others (Ogunyiyi 2012).

It emerged from the participants that some of the laboratories were makeshifts where no meaningful experiments could be carried out. Such a learning environment was not conducive to the learning of STEM Education. This concedes with curriculum implementation framework by Rogan and Grayson (2003), Hewson et al (2001), Molapo and Pillay (2018) who observed that negative environments may lead to learners disengaging from college and learning. As if providing a solution, the researcher considers that teachers' colleges should properly construct laboratories that are suitable and compatible to the 21st Century STEM Education. Properly construction laboratories would ensure sustainable resources in teacher education colleges.

Also emerging from the study was that there were shortages of equipment, chemicals and other paraphernalia in the laboratories in teacher education colleges. Laboratories lacked essential STEM equipment. As such the laboratories could not be used for carrying out experiments for STEM Education. Therefore, laboratories in teacher education colleges were not fully functional. This finding concurs with O'connor's (2016) observation that most schools, primary, secondary and colleges of education in Cameroon, Ghana, Tanzania and Uganda lacked functional laboratories. A functional laboratory would allow student teachers to carry out practical activities using equipment and consumables. Practical activities were not carried out in the laboratories. Practical activities were meant to reinforce theory. Yadar (2007) states that no costs in Science and Mathematics can be considered as complete without including some practical work. Additionally, UNESCO (2008) acknowledges that practical work forms an important part in any Science and Mathematics course. If student teachers did not do practical work, then STEM Education was incomplete because of lack of functionality of laboratories as resources. Deliberate efforts should be made to ensure that prerequisite chemicals and equipment are procured in teacher education colleges. This would enhance functionality of laboratories as a STEM resource in teacher education colleges. Alternatively, the teacher education colleges could form synergies with different stakeholders particularly industries that produce such consumables.

5.3.3 Available STEM Textbooks

Textbooks are a critical resource in the teaching and learning of STEM Education. The importance of textbooks cannot be over emphasised. The study established that teacher education colleges had textbooks in Physics and Computer Science for STEM Education. The availability of textbooks in colleges would ensure that essential resources for STEM Education. This is in line with curriculum implementation framework proposed by Rogan and Grayson (2003) under the construct capacity to innovate, under the sub construct physical resources, non-human resources like furniture or media centers, stationery and textbooks. Rogan and Grayson acknowledge that availability of the resource has a positive impact on the implementation of STEM.

It emerged from the study that textbooks were limited in Mathematics and Biology. This concurs with O'connor (2016)'s study of four African countries Uganda, Cameroon, Tanzania and Ghana which revealed that most of the schools, primary, secondary and colleges of education had limited textbooks. The shortage of textbooks as a resource hindered learning of STEM as acknowledged by Molapo and Pillay (2018). Additionally, in a study by Nwachukur et al (2000) on resources for teaching Biology in Lagos, it was revealed that there was a general inadequacy of resources for effective teaching and learning of Biology. The researcher considers that, deliberate efforts should be done by college management, college academic boards and college finance committees to procure requisite textbooks for Mathematics and Biology. Colleges of education can do fundraising and exhibitions to raise funds for the procurement of textbooks for the STEM departments.

The study also established that STEM textbooks that were available in teacher education colleges in the library were not current. The STEM textbooks in colleges of education were not of this decade. This was in contrast with observation made by Fowewe (2012) that libraries must be up to date. The teacher education colleges lacked up to date STEM textbooks in some subjects in the curriculum. Therefore, teacher educators and student teachers failed to access 21st Century STEM materials. The researcher inferred that student teachers taking biology and mathematics in primary teacher education colleges did not have adequate textbooks. This had a bearing on how STEM education was being implemented in primary education colleges in Zimbabwe. As if prescribing a solution, deliberate efforts should be done by college procurement committees and college academic boards to quickly process requisitions for the procurement of STEM resources for the colleges. Furthermore, Heads of Departments and Lecturers-in-charge of STEM departments should always update textbook resources in some subjects by making prompt requisitions for their departments to the college procurement committees.

5.3.4 Multimedia Resources

The study established that there was a multimedia technology center in the colleges of education. This finding resonates with Bhardway et al (2015) assertion that multimedia is concerned with computer- controlled integration of text, graphics, drawings, still and moving images, animation, audio or any type of information that can be represented, stored, transmitted and processed digitally. Furthermore, in a study by Bhardway et al (2015), multimedia is the emergence and convergence of modern technology that has brought significant changes in the field of Library and Information Science. Multimedia centers were of significance as helped the student teachers to get information which they wanted. This resource centers helped student teachers in researching for their STEM assignments.

5.3.5 Interactive Whiteboard

It emerged from the participants that interactive whiteboard was another resource available in teacher education colleges. The interactive whiteboard created motivation and zeal among students. This finding is coherent with Solvie's (2001) study that the interactive whiteboard was novel and created enthusiasm for learning on the part of students. Interactive whiteboard promotes student engagement when they touch and manipulate the text (Solvie, 2001). Additionally, engagement would be promoted through visual displays in form of diagrams, web and pictures as well as the use of colours and shapes (Solvie, 2001). The interactive whiteboard as a STEM resource used in the lab or classroom increased student engagement during the learning process.

5.3.6 STEM Workshop Support

The study established that different stakeholders such as UNESCO and the UZ DTE, funded workshops for professional development of teacher educators in teacher education colleges. The UNESCO sponsored workshops targeted teacher educators' ICT skills while the DTE workshops were meant for STEM curriculum design, development, research and implementation. All these workshops were targeting teacher educators' professional development. This was an example of outside support from different stakeholders. This was in sync with curriculum implementation framework proposed by Rogan and Grayson (2003) under the outside support construct of non-material support viewed as taking the form of in-service professional development and monitoring curriculum implementation. Teacher educators received professional development sponsored by different stakeholders. It was through such workshops that teacher educators improved their academic prowess. This would also help student teachers in STEM disciplines. A study by NCETE (2005) in America revealed that workshops had positive effects in helping the teachers to connect STEM Education with teaching practices and in return provide help to their students with enriching experiences.

The study also established that teacher educators did not attend the workshops organized by UNESCO. In contrast a study by NCETE (2005) acknowledged that to ensure maximum attendance by the teachers, the workshops were held in spring and summer during holidays in America. It was meant to reduce any interference with the teachers' respective teaching schedules. This was meant to benefit every teacher who intended to attend. The researcher considers that professional development workshops meant to support teacher educators should be organized and held during the holidays or on weekends, for example, Saturdays, such that every teacher educator is given the opportunity to attend.

It emerged from the study that professional development workshops were most likely done without proper needs assessment of the participants. On the contrary, the rational for the workshop is to meet the participants' needs and expectations (Westhoff, and Drougas, 2002). The identification of teacher educators' needs, interests and expectation would motivate and inspire the participants to attend professional development workshops as support measures to STEM implementation in teacher education colleges. Deliberate efforts to consider teacher educators' needs and interests should be a priority by workshop organizers. Workshop organizers should identify needs assessment of the teacher educators through say interviews or surveys. Also, teacher educators could give input through interactive meetings with workshop organizers and sponsors. This could make such workshops meaningful to teacher educators.

5.3.7 Available STEM Support Teacher Training

The study revealed that the Zimbabwean Government, DTE, ZIMDEF, Korea and JIKA extended a hand to teacher education colleges through training of Science and Mathematics teachers. The teachers were trained through various capacity development programmes initiated by government and its development partners. ZIMDEF initiated a training of Science and Mathematics through paying tuition for student teachers enrolled for STEM Education. JICA had projects in teacher education to strengthen Mathematics and Science subjects. These capacity development initiatives in Mathematics and Science were meant to strengthen and increase the number of STEM Education teachers and teacher educators. This finding resonates with Hibpshman's (2007) assertion that the ongoing professional development activities in Mathematics and Science should be extended to improve the content and skills of Science and Mathematics. The hallmark of these entire professional training in Science and Mathematics were meant to improve the quality of STEM teachers. This concurs with Kyere's (2017) study which revealed that teacher quality through professional development is also crucial in the teaching of STEM. All these initiatives by different stakeholders were meant to support human resource development in teacher education colleges. As such, Brown and Schulze (2002), Molapo and Pillay (2018) talked of human resource support being a good environment for the health of the welfare of the institutions. The training of STEM teachers was a good human resources development that would eventually increase their number and competencies. Such initiatives should also be extended to other STEM subjects in the college curriculum. However, the study established that the number of teacher education colleges mandated to train STEM teacher educators by the government and its development partners were only three out of fourteen in the country. This was an insignificant investment in STEM Education considering the number of STEM disciplines that were on offer. In contrast, Herrick (2011) opined that now is the time to make significant investment in Science Education, failure to implement these would lead to poor teaching methods and resourcefulness. In corroboration with Herrick (2011), government should deliberately increase the number of teacher education colleges offering STEM disciplines under the donor funded scheme.

5.3.8 Institutional Physical Infrastructure Support

Availability of institutional physical infrastructure in colleges of education is a key element to the provision of quality STEM Education. The study established that the government of Zimbabwe was providing infrastructure development support to teacher education colleges. Institutional physical support by government to teacher education colleges was a form of outside support. This is in line with the curriculum implementation framework proposed by Rogan and Grayson (2011) under the outside support construct. The outside support provided by government to teacher education colleges enhanced the construction of institutional infrastructure for STEM Education implementation. The institutional infrastructure support had seen the construction of laboratories, lecture rooms, libraries and lecture theatres for student teacher use. Institutional infrastructure is a key enabler in STEM teaching in teacher education colleges. However, the availability of institutional infrastructure support differed considerably with colleges. At College B, teacher educators indicated that there was no lecture theatre and some of the lecture rooms were converted into laboratories and part of the library was used as a lecture room. More so, during lectures, there was evidence of student overflow in lecture rooms. These were indications of limited infrastructure in teacher education colleges. This agreed with Gadzirayi et al (2016) study which revealed that the state of education infrastructure in most schools was deplorable. Zvavahera (2015) revealed that 90% of schools in Mazowe District were not offering science subjects due to unavailability of laboratories. The Malaysia Education Blueprint (2013-2025) also indicated that one of the factors that compromised student outcomes in STEM subjects was the limited infrastructure. In corroboration, the researcher's view was that limited infrastructure was because of inequality in the distribution of resources to teacher education colleges. Therefore, efforts should be made by the government to equitably distribute the limited resources available to teacher education, such that, STEM Education is effectively implemented.

5.3.9 Available STEM Policy

In developed countries where STEM has been introduced, there are STEM policies that support the innovation. In United Kingdom, for instance, a STEM policy paper was published in 2012 and drafted in May 2015 which stated that Science and Research were major contributors of prosperity for the United Kingdom. The government believe that they need high level skills in Science, Technology, Engineering and Mathematics (STEM) and citizens that value them (Department of Business, Innovation and Skills, 2015). In Zimbabwe there is the Science, Technology and Innovation policy guidelines meant to separate universities and colleges in terms of their operational realities. The government of Zimbabwe drafted the STEM policy to support the existence of STEM Education in teacher education colleges. The Science, Technology and Innovation policy of 2012 by the government was a form of outside support for teacher education colleges. This was in line with curriculum implementation framework by Rogan and Grayson (2003) under the construct Outside Agencies' Support. The government of Zimbabwe made effort to legalise STEM Education through statutory laws. The statutory laws protected teacher education colleges. This was in line with what was obtaining in the developed world where STEM Education was implemented first. The researcher was of the conviction that such policies gave teacher education colleges legal protection against any legal battle.

5.3.10 Available Retention Allowance Support

Maintaining low staff tenure and skilled STEM human resource through retention allowance by government was key to the preparation of pre-service teachers for STEM Education in teacher education colleges. This finding seemingly augurs with Heson, Kahle, Santlybury and Davis' (2001) study that one of the main indicators of access to quality science education was resources and teacher support. Rogan and Grayson's (2003) curriculum implementation framework under support from outside agencies talked about human resource support. The human resources being teachers, support needs to be given to STEM teachers in form of materials or financial incentives. Conversely, teacher educators indicated that retention allowances were no longer being paid because of the prevalent inflationary environment. There was no longer STEM human support. Resultantly, teacher turnover tends to increase as was observed by President's Council of Advisors on Science and Mathematics (PCAST, 2010), that the turnover on STEM in America particularly in Mathematics and Science could reach 25,000 annually. Furthermore, the report indicated that 40% of teachers decided they no longer wanted to teach because of lack of support. The researcher considered that there was need for government to reconsider introducing other tangible incentives either in monetary or non-monetary to reduce brain drain in teacher education colleges.

5.4 Basis for STEM Challenges in Teachers' Colleges

5.4.1 Incompetent College Leadership

Competent leadership is a key enabler in the preparation of pre-service teachers for STEM Education. In countries where STEM Education was a success like Malaysia, USA and Britain, the states had the blessing of competent leadership. Leadership in colleges also determined the success or failure of any curriculum initiative. The study established that the STEM challenges bedeviling teacher education colleges were, to some extent, because of incompetent leadership and general failure to understand the STEM concept. In contrast Unger et al (2008) opined that it is important to ensure that education leaders are knowledgeable about STEM Education to cultivate rich STEM learning experience and expertise in schools. It has been envisaged that leadership in colleges of education lacked primary STEM Education as they did not have background in primary school education. Such leaders were trained as secondary school teachers. The leaders failed to understand the primary education STEM curriculum. These leaders lacked knowledge of what the STEM curriculum in primary education should encompass. The leaders lacked experience and expertise of STEM Education at primary level. Undoubtedly, lack of experience and expertise affected the implementation of STEM Education in teacher education colleges. The researcher inferred that when executive appointments are made, especially for college principals, primary trained teachers with prerequisite skills and post-graduate qualifications should head primary teacher education colleges. This should also apply to secondary teacher education colleges. Such a move would enhance expertise in STEM Education. The basal qualifications of principals in teacher education colleges should be a master's degree or a doctorate degree in education, with a major thrust in primary education. Leadership in primary teacher education colleges should be well versed in pedagogical content knowledge in primary STEM curriculum. Primary pedagogical content knowledge is different from secondary pedagogical content knowledge. As such, leadership in primary teacher education colleges should have that knowledge such that they offer meaningful direction and guidance to the subordinates. Also, leadership appointments in teacher education colleges should purely be on merit such that they take primary teacher education to greater heights.

5.4.2 Shortage of STEM Teacher Educators

The teacher is at the chalk face of any curriculum implementation initiative. The teacher is a crucial factor in preparation of pre-service teachers for STEM Education. The success of any teacher preparation rests on the availability of the experienced and knowledgeable STEM educators. The study revealed that the challenges being faced by teacher education colleges in STEM teacher preparation was, mainly, shortage of STEM teacher educators because of high teacher turnover. This finding is coherent to the President's Council of Advisors of Science and Technology (2010) report that turnover yearly in the STEM teaching force particularly in Mathematics and Science discipline could reach 25 000. Additionally, the report indicates within the first five years of teaching, more than 40% of teachers decide they no longer wanted to teach due to lack of professional support. Such high teacher turnover led to shortage of STEM educators. Consequently, STEM educators are on demand regionally and globally. Many STEM teachers in

Zimbabwe were said to have left for greener pastures, in the region and internationally. Additionally, the teaching profession has failed to attract young people with knowledge and qualification because teaching was considered as a non-rewarding profession. As such, there was shortage of STEM teacher educators in colleges. Government should make deliberate efforts to pay teacher educators salaries that are competitive as they are obtaining regionally and globally. In America, for example, the government has increased and retained teachers in STEM teaching by allowing teachers to participate in professional development, help the teachers to achieve deep STEM content knowledge and mastery of STEM pedagogy. Furthermore, Advanced Level STEM students have been motivated to take up teaching as a profession through programmes such as Prepare and Inspire (PCAST, 2010). Such initiatives would go a long way in retaining STEM teachers in Zimbabwe.

5.4.3 Lack of STEM Knowledge by Teacher Educators

The knowledge of the teacher educator is equally important in STEM teacher preparation. Posamentier and Maeroff (2011) note that teachers who teach STEM programme matter. The study established that teacher educators who taught STEM Education were poorly equipped to teach STEM subjects, such as, Engineering. This finding seemingly concurs with Ejiwale's (2013) assertion that many classrooms are filled with underprepared individuals because they have received poor quality training or none. Relatively, teacher educators lacked knowledge of teaching Engineering. Traditional science teachers did not receive training in Engineering but were being asked to teach Engineering in teacher education colleges. Such teacher educators lacked teaching prowess in Engineering reflected through lack of knowledge. Posamentier and Maeroff (2011) posit that a typical elementary school teacher that has minimal elementary preparation in any STEM field tends to lack confidence in his or her knowledge of the subject. Undoubtedly, if teacher educators lacked confidence in STEM subjects, student teachers would also show the same traits. It is thus here suggested that during recruitment of teacher educators, there is need to consider those applicants who have traceable post-university industrial engineering experience. The STEM teacher educators could increase their knowledge in Engineering through professional development workshops and enrolling at colleges and universities in the country. The teacher educators could be exposed to Engineering course content such as, modeling how an engineering design challenge in the classroom can be done, solve design problems through practice, infuse engineering design in primary school curriculum and assessing engineering design.

5.4.4 Limited STEM Infrastructure

Adequate infrastructure is one of the key components in teacher preparation for STEM Education world over. This study revealed that in teacher education institutions there was limited STEM infrastructure such as lecture rooms because of high teacher: student ratio and facility incompatibility. This finding appears to concur with Gadzirayi et al (2016) that there is learning environment quagmire in the country. In the colleges there was overflow and overcrowding of students during the lecture times. Overcrowding in lecture rooms can stifle students' activities (Kruger and Whiteman, 2001). In the same view Ejiwale (2013) lamented the use of archaic facilities in colleges which do not match the demands of STEM. The limited STEM infrastructure created problems for STEM Education implementation. The interaction between teacher educators and student teachers was reduced. Such a scenario affected the type of methods used by the teacher educators. STEM Education by nature is ideal for low teacher student ratio. Also, the laboratories should have been constructed to STEM disciplines such that they are compatible especially, the ICT laboratories. Teacher education colleges have limited STEM infrastructure. Effort should be made by teacher education colleges to partner with industry and construct more lecture rooms. There is need for more concerted effort to form old student associations by the colleges such that more funds could be availed through old student boards.

5.4.5 Lack of Strong STEM Background

The recruitment process for initial teacher education in several countries is based on secondary education qualifications. In Finland there is a multi-step process for applicants, but they rely largely on secondary matriculation. The entrance tests are done through several processes. This is done to ensure that they recruit the best STEM candidate for initial teacher training (Parker, 2018). In New Zealand, recruitment is based on national certificate of national achievement with three subjects plus literacy and numeracy (Parker, 2018). In Ghana, recruitment is based on Ordinary Level passes, Science being compulsory to enter teacher education colleges (Kusi, 2017). The recruitment process in these countries ensured that the best candidate was selected into teacher education colleges, especially, in Finland.

The study established that student teachers enrolled in teacher education institutions lacked solid foundation in STEM Education and scientific knowledge. This finding concurs with PCAST's (2010) report which concluded that the 8th Grades who lacked proficiency found a mounting barrier as they experienced increased difficulty in STEM subjects due to lack of solid foundation in basic skills, such as, algebra. Most of the student teachers enrolled in teacher education colleges lacked STEM Education skills and knowledge because of weak Ordinary Level background. The student teachers would have done Integrated Science at Ordinary Level which was not as challenging as compared to the natural sciences. As such they lacked solid foundation in STEM Education.

5.4.6 Deficiency in Ideological Focus, Policy Inconsistency and Imposition

Political will determines successful implementation of any curriculum innovation initiative. The success story of STEM Education in America, United Kingdom and Malaysia had the blessings of political will. The ideological focus determined how policies were crafted. Such policies guided the implementation of the innovations. In Zimbabwe, the government seems to have lacked STEM ideological focus. This is in line with Chimbodza (2012) in Gadzirayi et al (2016) that the major problem in Zimbabwe is lack of ideological focus. Lack of ideological focus is lack of political will. This is characterised by failure to pursue an innovation to its end. In Zimbabwe, politicians made noise when a curriculum innovation is introduced. With the passage of time, the noise dwindles. For instance, today is STEM Education and tomorrow it is Education 5.0. Such lack of focus creates inconsistency and imposition.

Furthermore, this study established that government STEM policies were inconsistent and an imposition to teacher education institutions. This finding concurs with Gadzirayi et al (2016) study's that there was STEM policy inconsistency in the policy environment in the country. For instance, there are two ministries of education, namely: The Ministry of Primary and Secondary Education and the Ministry of Higher and Tertiary Education, Science, Innovation and Technology. These two ministries are pursuing STEM Education. Each ministry is developing its own STEM policy. As such, what one ministry does might be different from the other sister ministry. The existence of different STEM policies within one country leads to inconsistencies. This affects the implementation of STEM Education in the country. Additionally, teacher educators were concerned that such policies were being imposed on teacher education institutions. Such lack of consultation by policy makers led to resistance by teacher educators. The resistance by teacher educators was the cause of the challenges in implementing STEM Education in teacher education colleges. In contrast, in Hong Kong, the STEM Education policy of 2015 and 2016 were because of stakeholder consultation (Education Bureau, 2016). A two-month consultation was followed by feedback from various stakeholders in education and other sectors of the community (Education Bureau, 2016). Therefore, there was need for policy makers to consult different stakeholders when making policies. Also, there is need to harness policies between MOPSE and MHTESIT.

5.4.7 Inadequate Funding

In countries where STEM was implemented, for instance, in America, in 2004 the government invested 3.1 billion dollars for STEM Education initiatives. This was meant to recruit and support STEM teachers, colleges and universities (Obama, 2014). Furthermore, in United Kingdom funding was through Royal Academy of Engineering, British Academy, National Academies and Academy of Medical Sciences. The funding was meant to inspire students to study STEM programmes. The availability of funding enhances teacher preparation. Most countries that have implemented the STEM Education in the developed world received adequate funding from central government and other development partners. This study established that STEM Education is capital intensive but was inadequately funded. In contrast Herrick (2011) elaborated that now is the time to make significant investment in Science Education. Lack of investment and inadequate funding were the overarching obstacles to teacher education institutions. There were no major investments in college facilities for the implementation of STEM Education. Funds were inadequate to provide better STEM facilities. It was due to lack of funds that teacher education colleges failed to construct laboratories, lecture rooms, libraries, lecture theatre and procure requisite STEM consumables. These were essential ingredients for teacher preparation in STEM Education. Therefore, the central government should solicit private public partnerships (PPP) to invest in STEM Education in teacher education colleges.

5.5 Summary

This chapter discussed the findings of the study. These were discussed thematically, guided by the sub-research questions' themes, such as: teacher educator's knowledge, competences and skills in STEM Education; STEM delivery methods or strategies used in preparation of student teachers for STEM Education; requisite STEM resources, facilities and support systems available in colleges of education. Last, the chapter examined the basis for STEM inadequacies in teachers' colleges in fulfilling their mandate for the preparation of skilled STEM teachers. The next chapter summarizes the study, focusing on main ideas of the entire study, main findings, conclusions and recommendations emanating from the research findings. Overall, an effective STEM teacher preparation model was proffered.

CHAPTER 6
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.0. Introduction

The preceding chapter discussed the main findings of the study under sub-themes that were in line with the sub -research questions. This chapter provides the summary of the main ideas of the entire study, main research findings, conclusions of the study and recommendations from related Resultantly, a framework is proffered at the end of the chapter.

6.1 Summary of the Findings

6.1.1 Understanding STEM

STEM was the pinnacle for this study. It was prudent from the onset that participants be interrogated on their comprehension of the concept to ensure whether they had the requisite STEM Education experience. Understanding of STEM was also used as a measure of content knowledge and pedagogical content knowledge. The findings from the study revealed shared common understanding of STEM. The following were common expressions: acronym, fused, thematic, integrated, trans-disciplinary, incorporating all the four disciplines. Student teachers' definitions were more intriguing as they articulated deep understanding, focusing on problem-solving on issues affecting the community or the world.

6.1.2 Teacher Educators' Professional Competences

It was evident from the collected data that teacher educators were mature, well-educated with sound professional experience to provide informed views on the strategies used to develop student teachers for STEM Education in Zimbabwean teacher education colleges. The teacher educators were drawn from a wide spectrum of educational and professional background which ensured the researcher diversity on issues and opinions under investigation.

Regarding STEM competence, it was noted that teacher educators had subject matter knowledge, and pedagogical content knowledge. They were able to transform knowledge into activities, demonstration, analogies, simulation and adopt them to different students' abilities in STEM disciplines. Such STEM knowledge certainly enhanced the teaching of STEM Education in teacher education colleges. Furthermore, solicited data demonstrated that teacher educators were competent in incorporating STEM Education in the curriculum through crafting STEM syllabus, teaching programmes and course outlines. Crafting the said documents by teacher educators demonstrated knowledge of the subject, knowledge of goals, curriculum organisation and assessment. Overall, teacher educators were good in incorporating STEM Education. It was evident from data collected that one teacher educator in Science Computer Science was under qualified. The teacher educator had a Diploma in Education. Such a teacher educator lacked professional competence. Overall, the teacher educators were aware of the use value and purpose of STEM Education. They identified the 21st Century STEM skills gained through STEM Education, such as, creativity, critical thinking, collaborating, analytical and critical inquiry, while the purpose of STEM was stated as employment creation, industrialization and innovation.

6.1.3 Lack of STEM Knowledge in Engineering by Teacher Educators

The study established that STEM teacher educators were poorly equipped to teach Engineering. Teacher educators lacked knowledge of teaching Engineering as they did not receive any professional training in in the subject at college or university. It followed that pre-service teachers were not being adequately equipped with strategies required to teach Engineering.

6.1.4 Lack of Strong STEM Foundation by Student Teachers

The study revealed that student teachers lacked solid foundation in STEM Education and scientific knowledge. Student teachers had weak background in STEM. At Ordinary Level, the bulk of them had studied Integrated Science which was not as challenging as the natural Sciences. This had a negative impact on the preparation of student teachers for STEM Education in teacher education colleges.

6.1.5 Incompetent College Leadership

The respondents and participants were of the view that incompetent college leadership contributed to challenges because of lack of experience and expertise in primary education STEM curriculum. Leadership, in primary teacher education colleges was secondary trained. It was evident that such leadership was not competent enough to superintend STEM in primary curriculum.

6.2 STEM Delivery Methodologies or Strategies

Several teaching methods were used to prepare pre-service teachers for STEM Education in teacher education colleges. Some of the methods included these: discovery, project, cooperative, problem-solving, excursions, discussions and simulations. The study established that these methods were inquiry based and constructivist in nature. They were in sync with STEM methods obtaining globally and meet the 21st Century STEM pedagogy.

It was found from this study that teacher educators considered subject demand, learner's ability and diversity when selecting the STEM specific methods of teaching. Therefore, they differentiated STEM methods. On the other hand, student teachers had the feeling that teacher educators did not differentiate teaching methods according to subjects, especially, in ICT where storytelling was cited as a method of teaching STEM.

The study revealed that respondents believed that STEM teaching methods were adequate. The various teaching methods employed by teacher educators were problem-based learning and project-based learning. There was almost consensus that problem-based learning was critical and crucial in the teaching and learning of STEM Education in teacher education colleges. However, the study established that laboratory approach was not being used. The laboratory method is one of the most important STEM teaching methods. Student teachers did not carry out practical activities in the laboratory because there were no consumables. The student teachers did the theory part of the lectures without practical lessons. Student teachers found Chemistry lectures difficult to comprehend because of lack of practical lessons.

Research data testified that student teachers developed much knowledge from the teacher educators and applied the knowledge in schools during teaching practice. There were elements of scaffolding by the more capable peers. The learnt STEM teaching methods were applied by student teachers to teach learners in the schools they did teaching practice.

6.3 STEM Resources, Facilities and Support Systems in Teacher Education Colleges

6.3.1 Library Resources

The study envisaged that colleges had sound libraries with e- journals, for example, EBSCO Host, SAGE, JHOST, Francis Taylor and Emerald. Furthermore, the availability of multimedia technology, full ICT equipment, spot throw projectors and unlimited Wi-Fi connectivity for student teachers and teacher educators, enhanced STEM Education. The availability of library ensured that student teachers and teacher educators had STEM materials for preparation. However, library size at College B was reduced as part of it was used as Early Childhood Development lecture room. This thus deprived student teachers of effective library use. Furthermore, it emerged from this study that college libraries were inaccessible to student teachers. The primary teacher education timetable was congested, most of student teachers were non-resident and the non-availability of diesel for generators were factors that militated against the accessibility of the library by student teachers and teacher educators.

6.3.2 Laboratory Resources

The study revealed that laboratories were available in teacher education colleges for student teachers and teacher education colleges to design prototype, carry out experiments and solve real life problems affecting communities. However, it was further established that some of the laboratories were makeshifts where no meaningful experiment could be conducted. It also emerged from this study that laboratories in teacher education lacked equipment, chemicals and other paraphernalia, therefore, they were not functional. In such laboratories, student teachers and teacher educators could not carry out experiments for the different STEM disciplines on offer.

6.3.3 Textbook Resources

The respondents asserted that textbooks were available for Computer Science and Physics. However, the study indicated that textbooks were inadequate in Mathematics and Biology due to high student teacher enrolment in teacher education colleges. Such a scenario compromised the quality of assignment and the graduates from these teacher education colleges.

6.3.4 Multimedia resource

The study revealed that multimedia resource was available in teacher education colleges for student teachers and teacher educators to use for STEM teaching and learning. The resource enhanced information storage, representation and transmission. This resource motivated teacher educators in the learning of STEM education.

6.3.5 Interactive whiteboard resource

The respondents had the belief that interactive whiteboards were available in Chemistry, Biology, Physics, Computer Science and Mathematics. The interactive whiteboards enhanced the teaching and learning of STEM disciplines in teacher education colleges. The interactive whiteboard enabled effective and efficient interactions in teaching and learning of STEM Education in teacher education colleges.

6.3.6 Support Systems Available

6.3.6.1 STEM Workshops

The study established that there were different stakeholders funding workshops for professional development in teacher education colleges. Some of the sponsors were UNESCO and DTE. The teacher educators were trained in ICT skills, STEM curriculum design, development, research and implementation. Professional development workshops were meant to improve academic prowess. However, the study established that needs assessments were not effectively done prior to conducting the workshop. As a result, there was bad blood between workshop organizers and teacher educators. This impacted negatively on the preparation of pre-service teachers for STEM Education.

6.3.6.2 STEM Training

The study revealed that government, DTE, ZIMDEF, KOREA and JICA trained Science and Mathematics teachers through various capacity development programmes. The training was meant to strengthen and increase the number of STEM teacher educators in teacher education colleges. The increase in human resource would in the long run translate to increased teacher educators' competence in preparation of pre-service teachers for STEM Education. However, the study established that the number of Science and Mathematics teachers trained through the capacity development initiative programme was insignificant as only three colleges trained such teachers in the whole country.

6.3.6.3 Institutional Infrastructure

The availability of institutional infrastructure in teacher education colleges enhanced the construction of laboratories, lecture rooms, libraries and lecture theatres. However, the institutional infrastructure support was not equitably distributed in teacher education colleges. At College B the lecture theatre was not available. It was evident that student overflows characterised College B, particularly during 'mass' STEM lectures' time. This negatively affected the preparation of pre-service teachers for STEM Education in teacher education colleges.

6.3.6.4 STEM Policy

It was established that the Zimbabwean government instituted SI 2012, the Science, Technology and Innovation policy which separated colleges and universities. The policy gave STEM Education in colleges legal existence. It protected colleges against any legal battles. It legalized STEM Education.

6.3.6.5 Retention Allowance

The study unearthed the fact that government maintained skilled STEM human resources through payment of retention allowance to teacher educators in teacher education colleges. However, teacher educators indicated that the retention allowance was eroded by hyperinflation and it was eventually withdrawn. This contributed adversely to the preparation of pre-service teachers for STEM Education in teacher education colleges. Resultantly, teacher educators felt demotivated.

6.4 Basis for STEM Challenges in Teachers' Colleges

6.4.1 Shortage of STEM Teacher Educators

There were shortages of STEM teacher educators in the teachers' colleges. The shortage of teacher educators was because of high teacher educator turnover. The high teacher educator turnover was attributed to paltry salaries. This had a negative impact on the preparation of pre-service teachers for STEM education.

6.4.2 Policy Inconsistency and Imposition

Research data testified that there were policy inconsistencies and impositions on teacher education colleges by central government. Two ministries of education proffered parallel STEM policies. At the end of it all there were inconsistencies noticed as they were being operationalized. Such policies were never negotiated by their recipients or implementers. This created challenges in teacher education colleges in the preparation of student teachers for STEM Education.

6.4.3 Inadequate Funding

Teacher education colleges are not adequately funded by the central government and other development partners. This lack of investment had seen teacher education colleges failing to construct essential infrastructure and procuring consumables for laboratories and libraries. Lack of funding created challenges for the development of pre-service teachers for STEM Education in teacher education colleges.

6.4.4 Lack of Ideological Focus

The study established that STEM Education was marred by lack of ideological focus. The curriculum innovation was seemingly determined by the Minister who was at the helm by then. Most curriculum innovations were, regrettably, not being pursued to their end. Thus, this caused confusion in teacher education colleges.

6.5 Conclusions

The study sought to investigate implementation strategies used by teachers' colleges to develop pre-service teachers for STEM Education in Harare, Zimbabwe. The findings of the study revealed that teacher educators were skilled and competent in STEM Education. Teacher educators had content knowledge, pedagogical content knowledge, knowledge of the learners, knowledge for curricula and knowledge of STEM specific disciplines and topics. It was noted that teacher educators used several teaching methods to develop pre-service teachers for STEM Education. The numerous methods used included problem-solving, project method, inquiry-based methods and field trips. The teaching methods were STEM specific. The study indicated that teacher educators differentiated teaching methods. They had the capacity to use STEM specific methods obtaining globally for the 21st Century. The study revealed that teachers' colleges had libraries, laboratories, textbooks, multimedia centers and interactive whiteboard for STEM implementation. However, it emerged from the study that textbooks were in short supply in Mathematics and Science. Laboratories were available but they were not functional as there were no consumables to carry out experiments and practical in the laboratory.

The study established that government and other development partners rendered support to teachers' colleges. The support was in the form of professional development, construction of infrastructure, curriculum design, development and implementation of STEM education.

It emerged from the findings that the development of pre-service teachers for STEM Education faced a myriad of challenges that impeded its effectiveness. This included the issue of lack of STEM knowledge by teacher educators in teaching Engineering, coupled with shortage of STEM teacher educators with prerequisite skills and competence because of brain drain. Institutional infrastructure was another impediment: laboratories; lecture theatres were inadequate in colleges of education. Funding was inadequate as it impeded infrastructural development. Student teachers lacked solid foundation in STEM Education disciplines. On the issue of governance, there were policy inconsistencies and imposition which created some anarchy in colleges of education.

Furthermore, primary teacher education colleges were being manned by leaders who were secondary trained. These lacked knowledges of STEM curriculum at primary level.

6.6 Implication of the theories to the study

6.6.1 Rogan and Grayson (2003) Curriculum Implementation Theory

Several ideas outlined in Rogan and Grayson's curriculum implementation framework were reflected in this study. The findings on resources and facilities needed for STEM implementation in teacher education colleges echoed Rogan and Grayson's capacity to innovate construct. This construct outlines physical resources that should be available in the colleges for successful STEM implementation. The participants viewed workshops as one way of professional development for teacher educators. The view reflected Rogan and Grayson's notion on outside influence of curriculum implementation. Participants in this study acknowledged the support rendered by government, development partners and department of teacher education. This again reflected Rogan and Grayson's construct of outside influence on curriculum implementation. Additionally, the finding on incompetent primary education teacher's college principals is reflected in Rogan and Grayson's theory under the construct Capacity to Innovate, specifically, focusing on schools' ethos and management, where college management should have knowledge on the innovation being implemented. Furthermore, the finding on the need for Science practical work, where STEM discipline is taught without practical work is considered incomplete is embedded in Rogan and Grayson's theory under the construct Profile of Implementation. To add on the findings on teacher factor, teacher professional experience and competence are reflected in Rogan and Grayson's theory Under Capacity to Innovate, where teachers' professional experience and qualifications determine the success of curriculum implementation.

6.6.2 Constructivism Theory

Aspects of constructivism theory were imprinted in the findings of this study. The finding of teaching methods, such as, hands on, inquiry based, problem based, and project based are constructivist in nature. They reflect the constructivist's tendencies that knowledge is gained through social construction. The respondents indicated that student teachers employed the teaching methods taught at college during teaching practice. This reflected constructivist theory, particularly, Vygotsky's notion of the expert novice. The expert teaches the novice, and the novice applies the knowledge taught.

The foregoing discussion indicated that the Constructivist and Rogan and Grayson's (2003) theories informed this study. Constructivism informed the study on the teaching methods specific to STEM Education disciplines. Furthermore, constructivists acknowledge that knowledge is socially constructed. Thus, informing the study on how knowledge is constructed. Rogan and Grayson's (2003) curriculum implementation theory was very influential to this study. The resources, facilities and support for STEM Education was informed by this theory. The three constructs in Rogan and Grayson (2003) were pivotal in addressing the sub-research questions of this study.

The researcher was confident that the two theories informing this study were adequate as they managed to address critical research questions on methods used by teacher educators to prepare pre-service teachers for STEM Education.

6.7 Justification for the Methodology Used in this Study

The study used mixed methodology to interrogate implementing strategies used by teachers' colleges to develop pre-service teachers for STEM Education in Zimbabwe. The study was purely mixed method research. Quantitative and qualitative data were simultaneously collected in mixed research. Data were collected concurrently or sequentially (Criswell, 2004; Amakiri and Eke, 2019). The quantitative data in the form of numerals were collected through questionnaires for both teacher educators and student teachers. This helped the researcher to increase breadth of this study. Meanwhile, qualitative data in the form of words and narratives were collected from teacher educators, student teachers, university lecturers and directors in the Ministry of Higher and Tertiary Education, Innovation Science and Technology Development. This enabled the researcher to increase the depth of this study. Therefore, quantitative and qualitative data helped the researcher to give both breadth and depth to the research questions.

The concurrent triangulation design adopted in this study enabled the researcher to collect both quantitative and qualitative data at the same time from participants in teachers' colleges. The concurrent triangulation made use of convergence or confirmation of findings. The qualitative data from university lecturers, directors, teacher educators and student teachers were used to confirm the quantitative data from teacher educators and student teachers. This enabled the researcher to gather strong evidence for conclusion (Criswell, 2014). The methodology gave the researcher a wide range of choice on the data collection instruments. The researcher used questionnaires which were self-administered to the teacher educators and student teachers. The researcher also used face to face interviews which were administered to university lecturers, directors and student teachers. Focus group discussions were used to solicit data from teacher educators and student teachers, and documents review allowed the researcher to increase the depth on strategies used to develop pre-service teachers for STEM Education in teachers' colleges. The use of multiple data source enabled the triangulation of data which enhanced data credibility of the study. The triangulation of data gave the researcher well-balanced information from where the researcher could draw conclusions.

6.7.1 The Study's Contribution Towards New Knowledge

The researcher presents a conceptual, practical and simple framework to guide the Ministry of Higher and Tertiary Education Science, Innovation, Technology and Development, curriculum planners and implementers of STEM Education in teacher education colleges. The model is based on empirical findings of this study that reveal resources, facilities and support needed by teacher education colleges to prepare pre-service teachers for STEM Education. The model is called STEM Education Curriculum Implementation Model (SECIM).

6.8 The STEM Education Curriculum Implementation Model

The researcher developed a model that would guide the Ministry to improve STEM implementation in teacher education colleges in Zimbabwe. The proposed model is presented in Figure 41. The key processes and activities were drawn from the findings of this study which were ideas from the following sub-research question: What are the resources, facilities and support systems available in primary teacher education colleges for STEM implementation?

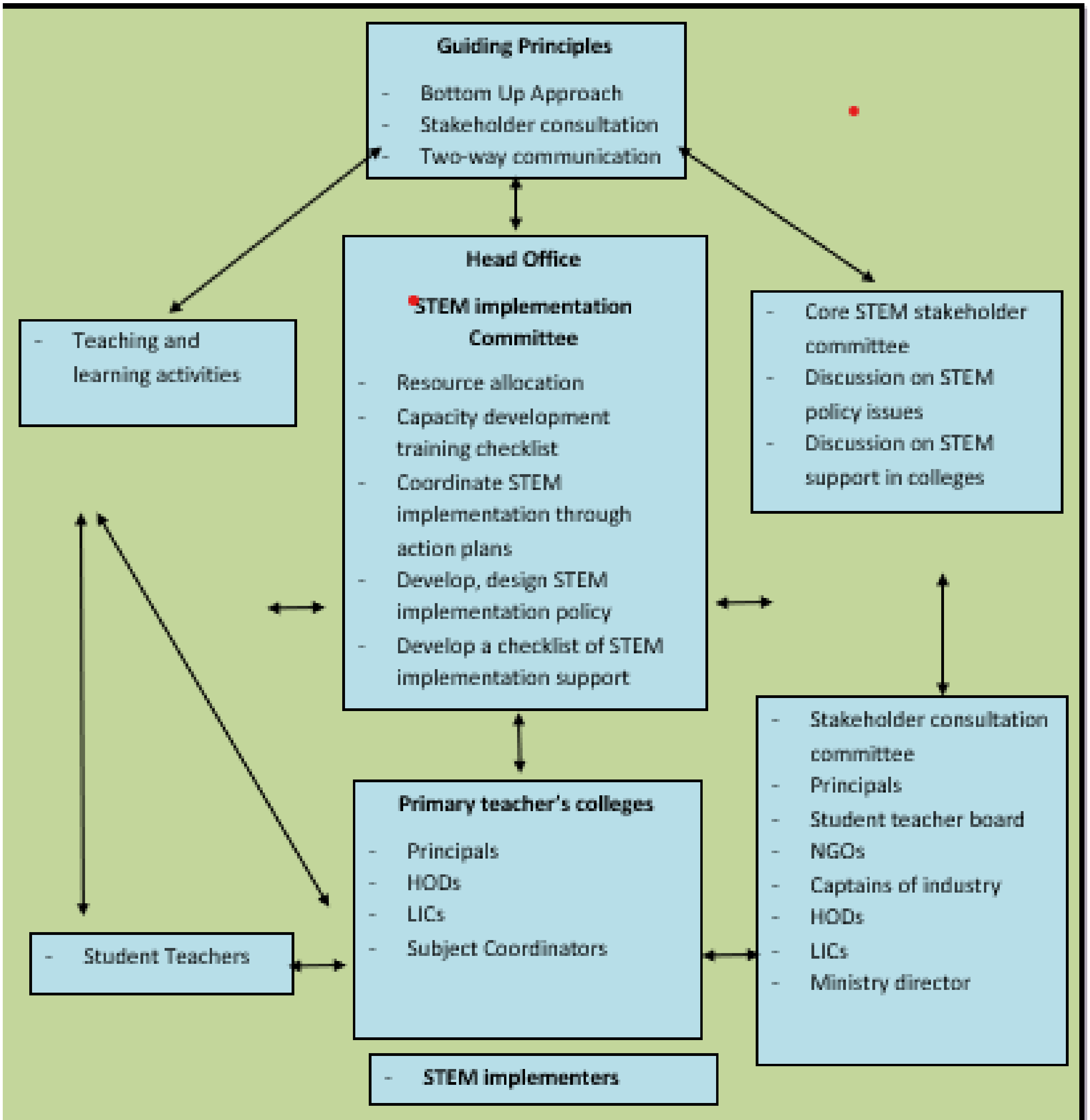

Figure 5. 1 Proposed STEM Education Implementation Model

The suggested model is illustrated above. At the core of the proposed framework is the STEM teacher. There are six constructs of the model. The model is guided by reviewed literature and findings from the study. The constructs are STEM policy, institutional physical infrastructure resources, STEM outside support, STEM teacher educator's knowledge, STEM delivery methodologies and college management. The following is description of each of the above constructs.

6.4.1 Institutional Physical Infrastructure

Infrastructure was denoted as a key enabler in the preparation of pre-service teachers for STEM education. The study acceded that STEM institutional physical infrastructure was limited, and laboratories were not functional, libraries were inadequate. There was need for heavy investment in STEM institutional physical infrastructure. As the current was no longer compatible.

6.4.2 The Teacher Educators STEM Knowledge and Competence

The study acceded that teacher educator's knowledge was of paramount. Teacher educators should be supported to attain high STEM education qualifications. Also, there

The suggested model is illustrated above. At the core of the proposed framework is the STEM teacher. There are six constructs of the model. The model is guided by reviewed literature and findings from the study. The constructs are STEM policy, institutional physical infrastructure resources, STEM outside support, STEM teacher educator's knowledge, STEM delivery methodologies and college management. The following is description of each of the above constructs. As illustrated in Figure 33. At the core of the proposed STEM curriculum implementation framework is the Head Office, which is the implementation committee. There are seven components to the model, namely: Head Office, STEM implementation committee, student teachers, teaching and learning activities, primary teacher education colleges, STEM stakeholder committee and stakeholder consultation committee.

6.9 Model Rationale

This proposed model is original. It contributes to STEM curriculum implementation in primary teacher education colleges in Zimbabwe. The researcher established that none of the proffered protocol exists.

Having explained the rationale of the model, the next section provided detailed explication of the framework components, activities and processes.

6.10 Model Components

6.10.1 Guiding Principles

a) Bottom Up Approach

The principle of bottom up approach allows input of different stakeholders to be factored in decision making process. All relevant stakeholders at all levels should be consulted; these include student teachers, teacher educators, college principals and college advisory boards. This approach would ensure ownership in the processes and activities of implementing STEM Education in primary teacher education colleges in Zimbabwe.

b) Two-Way Communication

Two-way communication channel should exist among all stakeholders. Two-way communication denotes democratic approach to decision making. Two-way communication allows instant feedback between and among stakeholders. The core STEM stakeholders' committee meeting should allow two-way communication where new ideas are deliberated and shared among the participants in the meeting.

6.10.2 Head Office STEM Implementation Committee

This committee has several functions that are outlined below. However, the committee structure would be as follows: director of tertiary education programme, curriculum specialists would be the head, followed by deputy director curriculum specialist. These would be responsible for developing a realistic action plan that would coordinate implementation of STEM Education at head office. The committee would coordinate policy on STEM implementation in teachers' colleges. Central coordination of STEM implementation would counter policy inconsistency and imposition, where two ministries of education do their own different policy issues with a lot of duplication of STEM activities.

- **Developing and Designing STEM Implementation Policy**

  This component would be responsible for policy development in the ministry. The development of policy would be informed by core STEM stakeholders' committee. This would enhance ownership of the policies.

- **Developing Checklist of STEM Implementation Activities in Colleges**

  The STEM implementation checklist would give principals, HODs, LICs, subject coordinators and lecturers a list of support available. It would ensure that all stakeholders are aware of the support in each teachers' college. This would ensure equity and transparency in resource allocation in teachers' colleges.

- **Capacity Development and Training**

  The committee on STEM implementation would continuously assess the training needs of teacher educators in STEM implementation. They would also identify the candidates for training, however, with input from the responsible teacher college.

6.10.3 Core STEM Stakeholder Committee

- **Discussion of STEM Support**

The core STEM stakeholder committee should encompass representatives of various stakeholders and Head Office STEM implementation committee. These different stakeholders would deliberate STEM implementation related issues generally and support issues particularly. STEM policies would also be shared during such discussions.

6.10.4 Constituent Stakeholder Committee

The individuals are from different constituencies who would represent the interest of their respective constituencies. These meet before core STEM stakeholder committee. The representatives make submissions to the core STEM stakeholder committee.

6.10.5 STEM Implementers

These are individuals who are at the chalk face. They are the implementers from the teachers' colleges. They include the principals, heads of departments, lecturers in charge, subject coordinators and lecturers. All would be supervised and supported on matters regarding STEM implementation in teachers' colleges.

6.10.6 Teaching and Learning Activities

The teaching and learning activities are about the strategies used to prepare student teachers for STEM education. It includes the teaching methodologies specific to STEM education and the interactions that take place in STEM Education lecture rooms. Additionally, it is about the knowledge of the teacher educators and the support teacher educators would need to effectively teach STEM Education in colleges.

6.10.7 STEM Student Teachers

The student teachers are the ultimate beneficiary of STEM implementation in teacher education colleges. The researcher is of the conviction that if all related challenges revealed by this study are counteracted, the student teacher would eventually benefit from STEM implementation in teachers' colleges.

6.10.8 Significance of the Model

The proposed model would provide sufficient STEM implementation protocol in teachers' colleges. This would ensure centrally coordinated STEM implementation. This model would enhance uniformity in STEM implementation in teachers' colleges.

The model assumes a bottom up approach of STEM implementation which involves consultation, two-way communication and is consumer driven. The model's ultimate beneficiary would be the student teacher, the most crucial role player. This model is not a closed system. Input is welcome from any component of the model.

6.11 Recommendations

The following recommendations are based on the findings for the study.

i. There should be an attempt to empower teacher educators and student teachers on the teaching of Engineering through STEM workshops held at teacher education colleges, led by experts from industry or training officers with Engineering background. Furthermore, STEM workshops should be decentralised to provincial level where student teachers are practicing.

ii. To ensure access to college libraries by student teachers on campus and practicum, the teacher education colleges should decongest primary teacher education timetable through integration of subjects or subject clusters, such that more time is available for research in the library. Furthermore, teacher education colleges should envisage providing data to both student teachers and teacher educators to counteract the problem of archaic textbooks and shortage of STEM textbooks in the libraries.

iii. The government through its development partners should invest in the construction of educational infrastructure, such as, libraries, functional laboratories, lecture rooms and lecture theatres. Furthermore, there is need for the central government to procure consumables for the college libraries and laboratories. Alternatively, colleges may mobilise financial resources through say levying student teachers or through college funded projects.

iv. There is need to ensure that laboratory activity method is used in teaching STEM Education in teacher education colleges. The use of laboratory approach would ensure the use of practical activities. Laboratory approach enhances marrying of theory and practice. Learning becomes meaningful through laboratory approach.

v. In teacher education colleges, STEM curriculum should encompass both theory and practice. Student teachers should be examined in both theory and practical work such that the course becomes complete. The graduates from such a course would fit well in any STEM Education environment.

vi. Teacher educators should differentiate methods in STEM instruction. There are STEM specific methods such as inquiry based. Other methods like storytelling should be used in non-STEM disciplines. The STEM Education skills that manifest through positivism are different from those obtaining in languages.

vii. Appointment of college principals who are specialists in primary education is underscored. This would enhance expertise and foster positive preparation of student teachers for STEM Education. There is a knowledge gap between primary education curriculum and secondary education curriculum. It can never be one size fits all.

viii. Recruit teacher candidates with a strong background in STEM Education. Teacher candidates to major in STEM Education should have natural Science passes at Ordinary Level. Such candidates should be mature and trainable. A strong background in STEM subjects would ensure continuity at teacher education colleges where they would be exposed to first year undergraduate pedagogical knowledge and competencies.

ix. There was need for stakeholder consultation by the government when crafting policies that are of national interest. The government should seek views of different stakeholders before instituting policies. Such a spirit would enhance collaboration and teamwork among stakeholders. Resultantly, such policies would be implemented in good faith. Teacher education colleges would embrace the initiative and ensure its success.

x. To maintain low staff turnover in teacher education colleges, government and colleges should introduce several incentives to STEM teacher educators. Such incentives should be meaningful and sustainable. Furthermore, teacher educator's salaries should match those obtaining in the region or be in sync with the prevalent economic trends of the nation.

xi. Government should ensure that whenever it introduces a curriculum innovation, it should be pursued to its logical conclusion. Abrupt u-turns and abortions should be avoided to ensure accountability in terms of resources.

6.12 Recommendations for Further Research

This study provided useful insights on the strategies used to prepare student teachers for STEM Education; further research should be carried out on assessing the implementation of STEM Education in teacher education colleges. This would give an informed evaluation for STEM initiative in teacher education colleges by policy makers.

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APPENDICES

APPENDIX A - ETHICAL CERTIFICATE

University of Fort Hare
Together in Excellence

ETHICS CLEARANCE
REC-270710-028-RA Level 01

Project Number:	REM031SCHI01
Project title:	**Implementing strategies used by teachers' colleges to prepare, preserve teachers for science, technology and mathematics in Zimbabwe.**
Qualification:	PhD in Education
Principal Researcher:	Ananias Chimwe
Supervisor:	Prof S Rembe
Co-supervisor:	N/A

On behalf of the University of Fort Hare's Research Ethics Committee (UREC) I hereby grant ethics approval for REM031SCHI01. This approval is valid for 12 months from the date of approval. Renewal of approval must be applied for BEFORE termination of this approval period. Renewal is subject to receipt of a satisfactory progress report. The approval covers the undertakings contained in the above-mentioned project and research instrument(s). The research may commence as from the 13/11/19, using the reference number indicated above.

Note that should any other instruments be required or amendments become necessary, these require separate authorisation.
Please note that the UREC must be informed immediately of

- Any material changes in the conditions or undertakings mentioned in the document;
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research.

The Principal Researcher must report to the UREC in the prescribed format, where applicable, annually, and at the end of the project, in respect of ethical compliance.

The UREC retains the right to

- Withdraw or amend this approval if
  - Any unethical principal or practices are revealed or suspected;
  - Relevant information has been withheld or misrepresented;
  - Regulatory changes of whatsoever nature so require;
  - The conditions contained in the Certificate have not been adhered to.
- Request access to any information or data at any time during the course or after completion of the project.

Your compliance with DoH 2015 guidelines and other regulatory instruments and with UREC ethics requirements as contained in the UREC terms of reference and standard operating procedures, is implied.

The UREC wishes you well in your research.

Yours sincerely

Professor Renuka Vithal
UREC-Chairperson
13 November 2019

APPENDIX B- INTRODUCTORY LETTER

Faculty of Education

School of Further and Continuing Education

Stewart Hall, Alice

Phone: Alice: 040602412

| Email:nmayiya@ufh.ac.za|

05 May 2019

The Principal
Morgan Zintec College
P.O. Box 1700
Harare
Zimbabwe

Dear Sir/Madam,

Re: Permission to Collect Data: Mr. A. Chimwe (Student Number201715046)

This is to confirm that Mr. Chimwe is pursuing PhD degree at the University of Fort Hare. His research title is **"Implementing strategies used by teachers' colleges to prepare pre-service teachers for Science, Technology, Engineering and Mathematics in Zimbabwe".** He is supposed to collect data from the Ministry of Higher and Tertiary Education, teachers' colleges, and Department of Teachers' Education University of Zimbabwe. Kindly grant him permission. I would also be grateful if you could kindly provide him with documents that may assist with information regarding the area of his study.

I would like to assure you that any information that will be collected will remain confidential and no name of a person will be disclosed. The student will ensure that he does not disrupt on going activities during the period he will be collecting data.

Sincerely

Prof. S. Rembe
Supervisor
Faculty of Education, Alice Campus
University of Fort Hare

APPENDIX C - LETTER REQUSTING FOR PERMISSION TO COLLECT DATA

ZIMBABWE

MINISTRY OF HIGHER AND TERTIARY EDUCATION, SCIENCE AND TECHNOLOGY DEVELOPMENT

All official communications should be directed to: "The Principal"

Telephone: 770534,771190, 781285/6, 752303

Reference:
MORGAN ZINTEC COLLEGE
P.O. Box 1700,Harare
ZIMBABWE

REF: CHIMWE A
E.C. NO: 0890222G

29 November 2019

The Permanent Secretary
Ministry of Higher and Tertiary Education, Innovation, Science and Technology Development

Att: Human Resources Director

PERMISSION TO CARRYOUT A RESEARCH IN PRIMARY TEACHER EDUCATION COLLEGES: CHIMWE A: PRINCIPAL LECTURER: EC NO: 0890222G: MORGAN ZINTEC COLLEGE: DEPT/STN: 2760/2500: MINISTRY OF HIGHER AND TERTIARY EDUCATION, SCIENCE AND TECHNOLOGY DEVELOPMEMNT

The above matter refers,

I am a Doctorial student at the University of Fort Hare in South Africa. I intend to access mainly two teacher`s colleges to solicit data associated with my PHD thesis. I intend to interface with a sample of 20 lecturers, 50 final year pre-serviced teachers and 2 directors in the ministry.

Research topic: Implementing strategies used by teacher education colleges to develop pre-service teachers for STEM education in Harare Metropolitan Province Zimbabwe

I appreciate in advance your usual cooperation.

Yours faithfully

Chimwe A
Principal Lecturer

APPENDIX D - LETTER FROM MINISTRY

All official communications should be addressed to:
"The Secretary for Higher & Tertiary Education
Telephones: 795891-5, 796441-9, 730055-9
Fax Numbers: 792109, 728730, 703957
E-mail: thesecretary@mhet.ac.zw
Telegraphic address: "EDUCATION"

ZIMBABWE

Reference:

MINISTRY OF HIGHER AND TERTIARY EDUCATION, INNOVATION, SCIENCE AND TECHNOLOGY DEVELOPMENT
P. BAG CY 7732
CAUSEWAY

REF: R/22/1

29 November 2019

Mr. Ananias Chimwe
C/o Morgan Zintec College
HARARE

AUTHORITY TO CARRY OUT RESEARCH IN THE MINISTRY INSTITUTIONS: MINISTRY OF HIGHER AND TERTIARY EDUCATION, INNOVATION, SCIENCE AND TECHNOLOGY DEVELOPMENT

Reference is made to your memo in which you requested for permission to carry out a research at one of the Ministry's institutions.

Accordingly, please be advised that the Head of Ministry has granted permission for you to carry out the research at Harare Polytechnic.

It is hoped that your research will benefit the Ministry and it would be appreciated if you could supply the office of the Permanent Secretary with a final copy of your study, as the findings would be relevant to the Ministry's strategic planning process.

MINISTRY OF HIGHER & TERTIARY EDU. SCIENCE & TECHNOLOGY DEV HUMAN RESOURCES 4
29 NOV 2019
P. BAG 7732, CAUSEWAY ZIMBABWE

Mubau P. (Mr)
Deputy Director -Human Resources
FOR: SECRETARY
HIGHER AND TERTIARY EDUCATION, INNOVATION, SCIENCE AND TECHNOLOGY DEVELOPMENT.

Cc: File

APPENDIX E - INFORMED CONSENT AGRREMENT

INFORMED CONSENT

I hereby agree to participate in research regarding implementation of strategies used to maintain positive discipline in Bulawayo Metropolitan Province Secondary Schools. I understand that I am participating freely and without being forced in any way to do so. I also understand that I can stop this interview at any point should I not want to continue and that this decision will not in any way affect me negatively.

I understand that this is a research project whose purpose is not necessarily to benefit me personally.

I have received the telephone number of a person to contact should I need to speak about any issues which may arise in this interview.

I understand that this consent form will not be linked to the interview, and that my answers will remain confidential.

I understand that if at all possible, feedback will be given to my community on the results of the completed research.

……………………………..

Signature of participant **Date**:…………………..

I hereby agree to the tape recording of my participation in the study

……………………………..

Signature of participant **Date**:…………………..

APPENDIX F- EDITOR'S DECLARATION

Treasure Pearls Academy Pvt. Ltd.

256 Samora Machel Avenue East, Eastlea

Harare, Zimbabwe

17 July 2020

TO WHOM IT MAY CONCERN

REFERENCE: THESIS EDITING, PROOFREADING AND FORMATTING

I hereby declare that the PhD thesis titled 'Implementing strategies used by teachers' colleges to prepare pre-service teachers for Science, Technology, Engineering and Mathematics Education in Harare metropolitan province in Zimbabwe' by Ananias Chimwe has been intensively edited and thoroughly proofread. I have checked for language use, corrected spellings, grammatical errors, paragraphing, eliminated observed language monotony, and ensured logical flow of text. It should, however, be underscored that the raised inadequacies were communicated to the author who had the prerogative to effect the suggested changes. Resultantly, the quality of the final product or thesis rests with the author who remains in full control of the writing process.

Yours Sincerely,

Dr Wilson Banda

PhD (SA); M.Ed. (UZ); B.Ed.; CE; Dip. Agric. (UK)

wilsonbda@gmail.com +263 772 881 050

ACADEMIC EDITOR

APPENDIX G - INTERVIEW GUIDE FOR DIRECTORS

1. What do you understand by STEM?
2. What are the STEM facilities in teacher's colleges?
3. What form of support are colleges getting from different stakeholders?
4. Briefly explain the nature of STEM infrastructure in teacher's colleges.
5. Is there a STEM policy in teacher's colleges?
6. What are the challenges facing teacher's colleges when implementing STEM education?
7. Why are teacher's colleges facing challenges when implementing STEM education?
8. Any comments on issue regarding implementation of STEM education in teacher's colleges?

APPENDIX H-INTERVIEW GUIDE FOR UNIVERSITY LECTURERS

1. What do u understand by STEM education?
2. What are the STEM facilities in teacher’s colleges?
3. What are the challenges facing teacher’s colleges when implementing STEM education?
4. Why are teacher’s colleges facing challenges when implementing STEM education?
5. Is there a STEM policy in teacher’s colleges?
6. Briefly explain the nature of STEM infrastructure in teacher’s colleges.
7. What form of support are teacher colleges getting from different stakeholders?
8. What are the STEM facilities in teacher colleges?

APPENDIX I - INTERVIEW FOR TEACHER EDUCATORS

1. What is your understanding of STEM?
2. Do you have any background on STEM education?
3. Comment on library resource in your college
4. What teaching strategies have you equipped your pre-service trainees with?
5. What is the importance of STEM education?
6. Do you feel competent to teach STEM education?
7. What support mechanisms are in place in colleges in implementing STEM education?
8. What resources and facilities are in place in your college to effectively prepare STEM pre-service teacher trainees?
9. Why are colleges facing challenges in implementing STEM education?
10. Comment on textbook resource in your STEM department.
11. Did you incorporate STEM education into the curriculum?
12. Comment on the laboratory resource in your college
13. Comment on the STEM policy in teacher education colleges.
14. Did you differentiate teaching methods during lectures?
15. Did student teachers use STEM teaching methods during teaching practice?

APPENDIX J - INTERVIEW SCHEDULE FOR PRE-SERVICE TEACHERS

1. What is your understanding of STEM?
2. What is the importance of STEM education?
3. Comment on library resource in your college
4. What teaching strategies were you equipped with and exposed to during your lectures?
5. Did you use STEM teaching methods during teaching practice?
6. What resources and facilities are available at colleges in implementing STEM?
7. Comment on the laboratory resource in your college
8. What support mechanisms are available colleges from other stakeholders in implementing STEM?
9. What aspects of teacher education you think need consideration to prepare pre-service teacher trainees to meet the challenges of STEM education?

10 Did teacher educators differentiate teaching methods during lectures?

APPENDIX K - FOCUS GROUP FOR TEACHER EDUCATORS

Guiding questions

1. What do you understand by STEM?

2. What teaching strategies do you equip pre-service teacher trainees?

3. Do you feel these strategies will enable them to effectively teach STEM classes?

4. What are your experiences with teacher competencies for STEM education?

5. Were you exposed to STEM education during your training?

6.Comment on the laboratory resource in your college

7. What resources and facilities are available in colleges for STEM implementation?

8 Why are teacher's colleges facing challenges in implementing STEM education?

9. Comment of library resource in your college

10. What support mechanisms are in place in colleges from different stakeholders in implementing STEM?

APPENDIX L - FOCUS GROUP FOR PRE-SERVICE TEACHERS

Guiding questions

1. What do you understand by STEM?
2. What teaching strategies were you equipped with during residential terms at college?
3. Do you think these strategies were relevant and adequate in enabling you to implement STEM education?
4. What facilities and resources available in colleges to support implementation of STEM education?
5. What challenges (if any) did you encounter in using the teaching strategies you were equipped with at college?
6. What support mechanisms are in place in colleges from different stakeholders?
7. Why are teacher's colleges facing challenges in implementing STEM education?
8. What are your suggestions (if any) for improvement of the strategies for implementing STEM education that pre-service trainees are equipped with during their training?

APPENDIX M - QUESTIONNAIRE FOR PRE-SERVICE TEACHER TRAINEES

Instructions

This questionnaire aims to establish the strategies used for implementing STEM education that you are equipped with during your residential period in college. Please answer all questions to the best of your ability. If a written answer is required, please print and if only an X is required select only one answer per question.

Demographic data

1.Please indicate your gender

Male	Female
1	2

2. Please indicate your age.

21-25	26-30	31-35	36-40	Above 40
1	2	3	4	5

3. Please indicate your knowledge level of STEM education.

Very high	High	Average	Not sure	Low	Very low
1	2	3	4	5	6

Knowledge of STEM education

4. What do you understand by STEM?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

5. how would you rate the competence of the teacher educators in STEM education?

Very incompetent	Slightly Incompetent	Moderately Competent	Competent	Extremely Competent
1	2	3	4	5

Give reasons for your rating in the above question.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

6. Rate the teaching strategies you are equipped with at college by your lecturers.

Poor	Average	Satisfactory	Good	Very Good
1	2	3	4	5

Give reasons for your rating in the above question.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

7. Rate on the functionality of the laboratories in your college.

Not Functional	Slightly Functional	Moderately Functional	Very Functional	Extremely Functional
1	2	3	4	5

Comment on your rating above.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

8. Rate on the availability of interactive whiteboard.

Not available	Not Sure	Available
1	2	3

Comment on your rating above.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

9. Rate on the availability of textbooks in your college.

Note available	Available
1	2

Comment on your answer.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

10. Rate on the support rendered to your college by the Department of Teacher Education.

Form of support	Agreed	Not sure	Disagree
Provision of support by DTE			
Provision of support by NGOs			

Any comments

……………………………………………………………………………………………………

……………………………………………………………………………………………………

11. Rate the STEM teaching methods used by teacher educators.

Very Poor	Poor	Fair	Good	Very Good
1	2	3	4	5

Comment on your answer above.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

12. How satisfying is differentiation of STEM teaching methods by teacher educators?

Not Satisfying	Slightly Satisfying	Moderately Satisfying	Very Satisfying	Extremely Satisfying
1	2	3	4	5

Comment on your response.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

13. Rate the adequacy of STEM teaching methods used by teacher educators.

Adequate	Not sure	Inadequate
1	2	3

Comment on your rating.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

14. How resourced is your college library in terms of STEM education delivery?

Not Satisfying	**Slightly Satisfying**	**Moderately Satisfying**	**Very Satisfying**	**Extremely Satisfying**
1	2	3	4	5

Comment on your rating above.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

15. Rate accessibility of the college library by student teacher's and teacher educators.

Very Inaccessible	**Slightly Accessible**	**Moderately Accessible**	**Very Accessible**	**Extremely Accessible**
1	2	3	4	5

Comment on your rating above.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

16. Rate on the adequacy of STEM laboratories.

Very inadequate	**Slightly Adequate**	**Moderately Adequate**	**Adequate**	**Extremely Adequate**
1	2	3	4	5

Comment on your rating above.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

17. What facilities are available in college to help you in teaching STEM classes?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

18. Do you consider your lecturers to be competent in STEM subjects Yes/ No.

…………………………………………………………………………………………………

If yes, please explain

……………………………………………………………………………………………………

……………………………………………………………………………………………………

19.May you make overall comments on your experience in college with reference to teaching strategies used for STEM classes.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

NB: Thank you for sparing your valuable time to respond to this questionnaire.

APPENDIX N - QUESTIONNAIRE FOR TEACHER EDUCATORS

This questionnaire is part of a study that is looking at the strategies used for implementing STEM education in teaching education in Zimbabwe. The study aims to establish what strategies pre-service teacher trainees are equipped with and the facilities and challenges faced during implementation. Thank you for sparing your valuable time to respond to this questionnaire.

Section A: Biographic Information

Insert an X for the appropriate response.

Write your pseudonym

……………………………………………………………………………

1.Gender

Male	Female
1	2

2. Age

20-30	31-40	41-50	51-60	Above 60
1	2	3	4	5

3. Lecturing experience in teacher education (in years).

1-5	6-10	11-15	16-20	Above 20
1	2	3	4	5

4. Your qualification

PhD	Master's Degree	Bachelor's Degree	Diploma in Education	Certificate in Education	Others Specify
1	2	3	4	5	6

5. State your current job title.

………………………………………………………………………………………………………

6. Name your department.

……………………………………………………………………………………………………

7. For how long have you served in the current position in terms of years?

1-5	6-10	11-15	16-20	Over 20
1	2	3	4	5

Section B: Knowledge of STEM education

8. What do you understand by STEM education?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

9. how would you rate the competence of the teacher educators in STEM education?

Very incompetent	**Slightly Incompetent**	**Moderately Competent**	**Competent**	**Extremely Competent**
1	2	3	4	5

Give reasons for your rating in the above question.

10. To what extent do your syllabi embrace STEM?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

11. What are the strategies of teaching STEM?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

12. Do you feel competent to teach STEM subjects? Yes/ No.

If yes, explain

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Section C: Implementation of STEM education.

Insert an X for the appropriate response

13. Rate the teaching strategies you equip your pre-service teacher trainees with.

Poor	Average	Satisfactory	Good	Very Good
1	2	3	4	5

14. What teaching strategies do you equip your pre-service teacher trainees with to enable them to enable effectively STEM classes?

………………………………………………………………………………………………………

………………………………………………………………………………………………………

15. Rate on the functionality of the laboratories in your college.

Not Functional	**Slightly Functional**	**Moderately Functional**	**Very Functional**	**Extremely Functional**
1	2	3	4	5

Comment on your rating above.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

16. Rate on the availability of interactive whiteboard.

Not available	**Not Sure**	**Available**
1	2	3

Comment on your rating above.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

17. Rate on the availability of textbooks in your college.

Note available	**Available**
1	2

Comment on your answer.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

18. Rate on the support rendered to colleges by different stakeholders.

Form of support	**Agreed**	**Not sure**	**Disagree**
STEM Workshop			
Provision of support by government			

Provision of support by NGOs	
Provision of support by DTE	

Any comments

……………………………………………………………………………………………………

……………………………………………………………………………………………………

19. What do you consider as teacher competencies to be able to teach STEM classes?

Incorporated	**Not Incorporated**
1	2

Comment on your response.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

20. What are some of the challenges you face when teaching pre-service STEM teacher trainees?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

21. Rate the STEM teaching methods used by teacher educators.

Very Poor	**Poor**	**Fair**	**Good**	**Very Good**
1	2	3	4	5

Comment on your answer above.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

22. How satisfying is your differentiation of your STEM teaching methods?

Not Satisfying	**Slightly Satisfying**	**Moderately Satisfying**	**Very Satisfying**	**Extremely Satisfying**
1	2	3	4	5

Comment on your response.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

23. Rate whether student teacher's used teaching methods they learnt at college during teaching practice.

Used	**Not Used**
1	2

Comment on you rating.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

24. Rate the adequacy of STEM teaching methods used by teacher educators.

Adequate	**Not sure**	**Inadequate**
1	2	3

Comment on your rating.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

25. How resourced is your college library in terms of STEM education delivery?

Not Satisfying	**Slightly Satisfying**	**Moderately Satisfying**	**Very Satisfying**	**Extremely Satisfying**
1	2	3	4	5

Comment on your rating above.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

26. Rate accessibility of the college library by student teacher's and teacher educators.

Very Inaccessible	**Slightly Accessible**	**Moderately Accessible**	**Very Accessible**	**Extremely Accessible**
1	2	3	4	5

Comment on your rating above.

………………………………………………………………………………………………

………………………………………………………………………………………………

27. Rate on the adequacy of STEM laboratories.

Very inadequate	**Slightly Adequate**	**Moderately Adequate**	**Adequate**	**Extremely Adequate**
1	2	3	4	5

Comment on your rating above.

………………………………………………………………………………………………

………………………………………………………………………………………………

28. Any other comments on strategies used for implementing STEM education.

………………………………………………………………………………………………

………………………………………………………………………………………………

University of Fort Hare
Together in Excellence

APPENDIX O - DOCUMENT REVIEW SCHEDULE

Attribute	Yes	No	Comment
1. Is the aspect of STEM available in the syllabus?			
2. Do the teaching programme and schemes reflect STEM teaching strategies?			
3. Do the lecture programmes refer to STEM content?			
4. Do the student notes match with lecturers lecturing programme?			
5. Do the lecture notes reflect teacher skills and competence for STEM education?			
6. Do lecture notes reflect coverage of STEM teaching strategies?			
7. Do the lecturers' notes reflect coverage of STEM content?			